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DISPLAY WORKING GROUP JOINT DARCOM/NMC/AFLC/AFSC PANEL ON THE F--ETC(U)
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INTERIM SUMMARY REPORT OF DISPLAY WORKING GROUP JOINT DARCOM/NMC/AFLC/AFSC PANEL ON THE FIELD OF NIGHT VISION TECHNOLOGY

16-17-18 JANUARY 1979

Approved for public release; distribution unlimited

Prepared by

AIR FORCE AEROSPACE MEDICAL RESEARCH LABORATORY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

For

JOINT DEPUTIES FOR LABORATORIES COMMITTEE
DEPARTMENT OF DEFENSE

NOTICES

TECHNICAL REVIEW AND APPROVAL

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Air Force Aerospace Medical Research Laboratory

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Some of the illustrations in this report are of poor quality, but should not hurt the overall usefulness for those informed about the subject matter.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

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Sensors (advanced)	Human Factors
Mission Requirements	FLIRs
Doctrinal Requirements	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

On 16, 17, and 18 January 1979, a Display Workshop, sponsored by the Display Working Group of the Joint Deputies for Laboratories Committee on Night Vision Technology Panel, was held at the Naval Ocean Systems Center, San Diego, California. The purpose of this workshop was "to define the doctrinal and system requirements driving advanced diaplay technology for next generation FLIR applications." To achieve this purpose, seven sessions were conducted. Four were tutorial in nature and three were discussion forums. The tutorial sessions (Sessions I, II, III, and VI) covered the topics of (SEE REVERSE)

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mission/doctrine requirements, system requirements, human factors and sensor/display state-of-the-art. The discussion sessions (Sessions IV, V, and VII) provided the attendees with the opportunity to interact with one another as well as to enter into informative and effective dialogue. Session IV served as a "question and answer" period for topics covered in the first thres sessions; Session V covered the topic of defining common terms used within the sensor/display community and developing standardized image measurement techniques; while Session VII served as a summary session whereby attendees attempted to summarize what had transpired at the Workshop. This report documents, in a concise and coherent manner, the proceedings that occured during the conduct of this Workshop. A summary of each session is provided along with summary papers and associated presentation materials submitted by participants.

Preface

This manuscript documents the proceedings of the Display Workshop held at the Naval Ocean Systems Center (NOSC), San Diego, CA on 16, 17, and 18 January 1979. The Workshop was sponsored by the Display and the Sensor Working Groups of the Joint Deputies for Laboratories' Night Vision Technology Panel (JDL-NVT). Preparation of this document was accomplished by Mr. William N. Kama, Mr. Wayne L. Martin and Mr. Gilbert G. Kuperman under Project 7184, Task 718411, Work Unit 71841129, "Tri Service-Subpanel on Displays."

The editors would like to express their sincere appreciation to those individuals who helped make the Workshop such a success by serving either as a session chairman and/or presenting a paper. They would like to express special thanks to Mr. Parviz Soltan, NOSC, who handled all of the arrangements for the Workshop and to Ms. Teresa Marshall who was responsible for the typing of this document.

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* See Mr. Colombo's presentation in Session I.

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AGENDA
Tri-Service Display Workshop
16-18 January 1979
Naval Ocean Systems Center
Building 33 - Cloud Room & Crow's Nest

16 January 1979

0800 - 0820	Registration	
0820 - 0830	Welcome Address	Dr. Howard Blood, Tech Director, NOSC Mr. W. Martin, Chairman, Display Subpanel
0830 - 0845	JDL-NVT Panel	Mr. R. Fulton, Exec. Sec'y, NVT Panel

Session I - Mission/Doctrinal Requirements

OBJECTIVE: To provide attendees with insight as to how doctrine/mission requirements are derived and identify what these requirements are. (Dr. Roy Frick, Chairman)

0845 - 0905		Dr. R. Frick, ASD/XROL
0905 - 0925		Mr. Steve Kay, ASD/AERS
0925 - 0945		Lt Col C. Ohlenburger, USAAC
0945 - 1005		Mr. Joseph Colombo, NADC
1005 - 1015	Break	

Session II - Systems Requirements

OBJECTIVE: To acquaint attendees with the process that the system engineer uses to evolve a system that will meet the needs defined by the doctrine/mission requirements. (Mr. Wayne L. Martin, Chairman)

1015 - 1035		Maj J.J. Armstrong, ASD/YPRS
1035 - 1055		Mr. H. Waruszewski, ASD/ENAIC

1055 - 1115		Dr. R. Frick, ASD/XROL
1115 - 1135		Col Patnode, AAH
1135 - 1155		Mr. J. Colombo, NADC
1155 - 1215		Lt Tom Mitchell, NADC
1215 - 1330	Lunch	

Session III - Human Factors

OBJECTIVE: To delineate those visual human performance factors which must be borne in mind during the development cycle of a given system. (Mr. John Reising, AFFDL, Chairman)

1330 - 1400	Human Visual Systems & Displays	Dr. F. Holly, USAARL
1400 - 1430	Display Types	Dr. K. Burnette, Bunker-Ramo
1430 - 1500	Display Modes & Subject Tasks	*Mr. W. Carel, Hughes AC
1500 - 1515	Break	
1515 - 1545	Measures of Display Quality	Dr. H. Snyder, VPI
1545 - 1615	Sensor/Display Parameters	Dr. H.L. Task, AMRL/HEA
1615 - 1700	Discussion of Day's Session	Mr. W.L. Martin, AMRL/HEA
1800 -	No-Host Cocktail Party	NOSC Officers Club, Adm. Kidd Room

17 January 1979

Session IV - Interrelationship and Impact of Mission Needs, System Requirements, and Human Factors on Display Needs

OBJECTIVE: To determine how topics covered in Sessions I, II and III interrelate and what impact each has upon the other and upon advanced display requirements.

*Paper available in proceedings but not presented at workshop.

0815 - 1015	Open Panel Discussion	Capt Robert Verona, USAARL, Moderator
1015 - 1030	Break	

Session V - Terminology

OBJECTIVE: Establish agreement as to the interpretation of terms being used within the sensor/display community.

1030 - 1200	Presentation/Discussion of Terms	Dr. H. Lee Task, AMRL/HEA, Moderator
1200 - 1300	Lunch	

Session VI - Sensor/Display State of the Art

OBJECTIVE: Acquaint attendees with current state-of-the-art in displays and sensors. (Capt David Hake and Dr. Elliot Schlam, Co-Chairmen)

1300 - 1320	Sensor Overview	Capt D. Hake, AFAL/RWI
1320 - 1340	Pave Tack	Mr. R. Siewecki
1340 - 1400	FLIR Tech Demo	Mr. A. Grandjean, AFAL/RWI
1400 - 1440	ATAC	Mr. S. Layman, NV&EOL
1440 - 1450	Break	
1450 - 1510	Display Overview	Dr. E. Schlam, USAERADCOM
1510 - 1530	CRTs	Mr. H. Waruszewski, ASD/ENAIC
1530 - 1550	Direct View CRTs	Dr. E. Schlam, USAERADCOM
1550 - 1610	HUDs	Mr. J. Mysing, AFAL/AAT
1610 - 1630	HMDs	Mr. J. Brindle, NV&EOL

1630 - 1650	Pave Tack Displays	Mr. S. Kay, ASD/AERS
1650 - 1730	Discussion of Day's Sessions	Mr. W. Martin, AMRL/HEA

18 January 1979

Session VII - Executive Session

OBJECTIVE: Assess what transpired at workshop and to generate recommendations regarding future research efforts, future development efforts, and future activities in the display area. (Mr. Wayne Martin, Mr. James Brindle and Mr. William Mulley, Co-Chairmen)

0815 - 1015	Discussions/Recommendations	
1015 - 1030	Break	
1030 - 1200	Discussions/Recommendations	
1200 - 1300	Lunch	
1300 -	Tour of NOSC's LCX Large Screen Display and Time Encoded Special Display Facilities	(For those interested)

ATTENDEES
TRI-SERVICE DISPLAY WORKSHOP
NOSC, SAN DIEGO, CA
16-18 JAN 1979

NAME	MAILING ADDRESS	PHONE
ARMSTRONG, John J., Maj	ASD/YPRS Wright-Patterson AFB OH 45433	AV 785-5812
ARNOFF, Howard,	Naval Air Systems Command AIR-5313C Washington, D.C. 20361	AV 222-7488
BREITMAIER, William A.	Naval Air Development Center ACSTD (Code 6022) Warminster, PA 18974	AV 441-2889
BRINDLE, James	Commander Night Vision & Electro- Optical Laboratory ATTN: DELNV-EOD Ft. Belvoir, VA 22060	AV 354-5368
BURNETTE, Keith, Dr.	Bunker-Ramo Corp. Suite 302 4130 Linden Ave. Dayton, OH 45432	(513) 254-1793
COLOMBO, J.	Naval Air Development Center ATTN: Code 6022 Warminster, PA 18974	AV 441-2088
DWORZAK, Willis	Commander US Army Avionics Research and Development Activity ATTN: DAVAA-I Ft. Monmouth, N.J. 07703	AV 995-4391
FILARSKY, S.	Naval Air Development Center ATTN: Code 6022 Warminster, PA 18974	AV 441-2088 (215) 441-2088
FRICK, Roy, Dr.	ASD/XROL Wright-Patterson AFB OH 45433	AV 785-6396

FULTON, Richard	Director US Army Electronics R&D Command Night Vision & Electro-Optics Laboratory ATTN: DELNV-D Fort Belvoir, VA 22060	AV 354-3923
GARRETT, Harold	AFML/LTE Wright-Patterson AFB OH 45433	AV 785-5177 -5607
GRANDJEAN, Andy	AFAL/RWI Wright-Patterson AFB OH 45433	AV 785-5922 (513) 255-5922
GURMAN, Brad	Commander US Army Avionics Research and Development Activity ATTN: DAVAA-E Ft. Monmouth, N.J. 07703	AV 995-4201
HAKE, David, Capt	AFAL/RWI Wright-Patterson AFB OH 45433	AV 785-5922 (513) 255-5922
HOFFMAN, Mark, Dr.	USAHEL/USAAVNC ATTN: DRXHE-FR P.O. Box 476 Ft. Rucker, AL 36362	AV 558-3303
HOLLY, Frank, Dr.	Commander USA Aeromedical Research Ft. Rucker, AL 36362	AV 558-6808 (205) 255-6808
KAMA, William	AMRL/HEA Wright-Patterson AFB OH 45433	AV 785-4820
KAY, Steve	ASD/AERS Wright-Patterson AFB OH 45433	AV 785-3766
KING, William J.	NAVAIR DC 20361 AIR-53352D	AV 222-0754
KRUEGER, Gerald P., Dr. Capt	US Army Aeromedical Research Lab Fort Rucker, ALA 36362	AV 558-3211 -6504
KUPERMAN, Gil	AMRL/HEA Wright-Patterson AFB OH 45433	AV 785-4693

LAYMAN, Stuart	Commander Night Vision & Electro- Optical Laboratory ATTN: DELNV-VI Ft. Belvoir, VA 22060	AV 354-2735
MARTIN, Wayne	AMRL/HEA Wright-Patterson AFB OH 45433	AV 785-4820
MELNICK, Walt	Air Force Flight Dynamics Lab AFFDL/FGR Wright-Patterson AFB OH 45433	AV 785-5546 (513) 255-6616
MITCHELL, Thomas, Lt	Naval Air Development Center ACSTD (Code 6022) Warminster, PA 18974	AV 441-2889 -2890
MOWERY, Gary W., Cdr	Naval Air Systems Command Washington D.C. 20361	AV 222-5668 PMA 261-21
MULLEY, William	Naval Air Development Center ATTN: Code 6022 Warminster, PA 18974	AV 441-2411
MYSING, John	AFAL/AAT Wright-Patterson AFB OH 45433	
OHLENBURGER, Cliff, Lt Col	Commander USA Aviation Center ATTN: ATZQ-D-MA	AV 558-3937 -2406 -4872
PATNODE, Col	Project Manager TADS/PNVS ATTN: DRCPM-AAH-TP Box 209 St. Louis, MO 63116	AV 698-3995 -3996
REDFORD, Joeseph	Commander US Army Aviation R&D Command ATTN: DRDAV-EXA PO Box 209 St. Louis, MO 63166	AV 698-5666
REISING, John Dr.	AFFDL/FGR Wright-Patterson AFB OH 45433	AV 785-6895

RUSSO, Luici	Naval Air Development Center ATTN: Code 6022 Warminster, PA 18974	AV 441-2088
SCHLAM, Elliott, Dr.	Commander US Army Electronics R&D Command ATTN: DELET-BD Ft. Monmouth, N.J. 07703	AV 996-5225
SIMONS, John	Systems Research Labs, Inc. Dayton, OH 45432	(513) 426-4051
SIWECKI, Ron	ASD/AER-EA Wright-Patterson AFB OH 45433	AV 785-3591
SOLTAN, Parviz	Department of the Navy Naval Ocean Systems Center Code: 811 271 Catalina Blvd. San Diego, California 92152	AV 225-6725 (714) 225-6725
SNYDER, Harry, Dr.	Virginia Polytechnic Inst. and State University Human Factors Laboratory Dept. of Industrial Engineering and Operations Research Blacksburg, VA 24061	(703) 961-5358
TSAPARAS, George	Naval Air Systems Command Code Air 340 Washington D.C. 20361	AV 222-7419
VERONA, Robert, Capt	Commander USA Aeromedical Research Laboratory Ft. Rucker, AL 36362	AV 558-6415 -6319
WARUSZEWSKI, Harry	ASD/ENAIC Wright-Patterson AFB OH 45433	AV 285-4400
WHITTED, Harry A.	Naval Ocean Systems Center Code 8235 San Diego, CA 92152	AV 933-7631 (714) 225-7631

EXECUTIVE SUMMARY FOR THE TRI-SERVICE DISPLAY WORKSHOP
16-18 JANUARY 1979

Introduction

On 16-18 January 1979, a Tri-Service Display Workshop was held at the Naval Ocean Systems Center (NOSC), San Diego, California. The Workshop was jointly sponsored by the Display and the Sensor Working Groups of the Joint Deputies for Laboratories' Night Vision Technology Panel (JDL-NVT). The purpose of the Workshop was "to define the doctrinal and system requirements driving advanced display technology for next generation airborne FLIR applications."

A total of forty-two (42) individuals representing the mission/doctrine area, the systems area, the technology development area (display and sensor), and the human factors performance area from various agencies within the Air Force, Army and Navy as well as several invited speakers from industry and academia participated in the Workshop. The makeup of this Workshop was significant in that it was the first time individuals representing all of these disciplines had been brought together to address a specific problem (i.e., advanced display requirements) in order to offer possible solutions.

To achieve the purpose of the Workshop, seven sessions were conducted. Four were tutorial in nature and three were discussion forums. The tutorial sessions (Sessions I, II, III and VI) covered the topics of mission/doctrine requirements, system requirements, human factors, and sensor/display state-of-the-art. Taken as a whole, the first three sessions were intended to acquaint the attendees with those various factors -- mission/doctrine,

system, and human -- which must be kept under consideration during the development of a weapon system, especially with respect (in this case) to the display subsystem. The final tutorial session (Session VI) provided attendees with an overview of the current state-of-the-art in sensor/display technology as well as a look at emerging technological developments in these two areas.

The discussion sessions (Sessions IV, V and VII) provided the attendees with the opportunity to interact with one another as well as to enter into informative and effective dialogue. Session IV served as a "question and answer" period for the topics covered in the first three sessions; Session V covered the topic of defining common terms used within the sensor/display community and developing standardized image measurement techniques; while Session VII served as a summary session whereby attendees attempted to summarize what had transpired at the Workshop and identified what recommendations, research problems, etc., if any, could or should be posited for future consideration by the Display Working Group to its parent panel, the Night Vision Technology Panel.

Purpose and Organization of this Document

The purpose of this Executive Summary is to document, in a concise and coherent manner, the proceedings that occurred during the conduct of this Workshop. As a matter of convenience, the organization of this document will follow the outline of the agenda (page ii) used for the Workshop. A summary of each session is provided. Summary papers and associated presentation materials submitted by the participants are included in the proceedings section of this document. No attempt has been made at critiquing each paper presented, but whenever a possible problem area was surfaced during the presentation of a paper, such problems have been identified.

Opening Session

The opening session was devoted to the welcoming of the attendees and the handling of last minute administrative and technical matters.

Dr. Howard Blood, Technical Director for the Naval Ocean Systems Center and host for the Workshop, welcomed the attendees on behalf of his organization and wished them a successful and productive Workshop. He also spoke briefly about his experiences in night bombing utilizing radar and stressed the importance of and the need for research in the night vision area.

Mr. Wayne L. Martin, Chairman of the Display Working Group, also welcomed the attendees to the Workshop. After making several administrative announcements pertaining to the conduct of the Workshop, he introduced Mr. Parviz Soltan (NOSC), coordinator for the Workshop, who would be available to assist attendees with problems they might have; and Mr. William N. Kama, Executive Secretary for the Display Working Group, to whom all presentation materials were to be given.

The final speaker in the opening session was Mr. Richard Fulton, Executive Secretary for the Night Vision Technology Panel. Mr. Fulton gave a brief historical account of the NVT panel. It was founded in May 1974 by agreement of the Joint Laboratories' Commanders (DARCOM/NMC/AFLC/AFSC). The purpose of the panel is to develop common technology goals for DoD. Its function is to (1) identify tri-service requirements, (2) develop technology plans for specific problem areas, (3) encourage tri-service interaction and communication, and (4) reduce the expenditure of R&D funds through interdependent research programs. Mr. Fulton also discussed the Panel's many working groups, how they interact among themselves and interface with the parent panel.

Session I - Mission/Doctrinal Requirements

The first session of the Workshop was chaired by Dr. Roy Frick, General Purpose and Airlift Division, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. This session dealt with the mission/doctrine area and its objective was "to provide attendees with insight as to how mission/doctrine requirements are derived and identify what these requirements are." In addition to Dr. Frick, three other speakers made presentations during this session. They were Mr. Steve Kay, Reconnaissance/Strike SPO, Aeronautical Systems Division; Lt Col Cliff Ohlenberger, Directorate of Combat Development, Ft. Rucker, Alabama; and Mr. Joseph Colombo, F-14 CILOP Office, Naval Air Development Center, Warminster, Pennsylvania.

Dr. Frick's presentation focused on the derivation of mission/doctrine requirements. He stressed that the major factors that determine these requirements are the threats to be dealt with (type and density) and the operating environment (terrain and weather). He pointed out that the most severe operating environment is found in the central European theater. He stated that to be successful in this particular environment, we need to improve productivity. That is, we must increase both the number of sorties per day and the number of kills per sortie. To illustrate how mission/doctrinal considerations are derived, Dr. Frick discussed a study sponsored by his activity on one vs two seat target acquisition/weapon delivery which was aimed at identifying how technology might alleviate crew workload during target acquisition and weapon delivery.

Mr. Kay's presentation dealt with the Advanced Laser Designation (ALD) system being developed for incorporation in the F-16 aircraft. In particular, he focused on the approach used by his group to arrive at the final

system configuration. They used a six-step approach which consisted of (1) learning about the available technology, (2) studying the critical areas, (3) putting a study team together, (4) preparing the requirements specifications, (5) going to a multiple source solicitation, and (6) making a dual award. (Unfortunately, Mr. Kay's presentation was not available for inclusion in the proceedings.)

Lt Col Ohlenberger discussed how requirements are generated in the Army. He stated that his office was in the process of evolving the Army's aviation requirements for the 1986-1996 time frame. He also pointed out that the Army's principal combat developer is TRADOC and that many of the requirements are generated through them. Lt Col Ohlenberger then discussed the many different ways in which a requirement may be initiated, e.g., from someone in the field, changes in threat capabilities, etc., and the form that it takes (letter of agreement, letter requirement or required operational capability) in the Life Cycle Management model. He then discussed the Combat Development Process (CDP). This process defines how the Army decides what to buy and indicates at what point in the time line inputs to the major material acquisition decisions should be made. Lt Col Ohlenberger also talked about Army aviation in the high threat environment in which he discussed (1) requirements that were general in nature (to provide a basic understanding of conditions under which Army aviation must operate); (2) some broad capabilities and requirements that are not specifically aircraft-type sensitive, and; (3) a few of the requirements documents in which the specific characteristics are found.

Mr. Colombo discussed the Navy's F-14 CILOP study, i.e., Conversion in Lieu of Procurement, which is aimed at increasing the capability of the current aircraft to successfully perform the maritime air superiority (MAS)

mission. To achieve this capability, the needs identified were air superiority, all weather, day/night, and long/short range. Missions identified were fleet air defense, strike escort, and air-to-surface attack. This upgrade in capability will increase the aircraft's effectiveness against manned bombers and missiles. Mr. Colombo then discussed some of the techniques used to arrive at the decisions made. For example, a technology survey was made to establish the baseline for the aircraft as well as to determine the state-of-the-art of equipment available in 1980; evaluations of various subsystems were based on the criteria of performance, risk, cost, and schedule; evaluations of various system alternatives were based on performance, risk, integration, and schedule; and, finally, a system analysis approach to determine the effectiveness of the system was performed using number of kills (system effectiveness) and dollars per kill (cost effectiveness).

In reviewing the papers presented in this Session, it would appear that the major factors driving mission/doctrine requirements are: (1) the available technology; (2) the type and density of threats to be encountered, and; (3) the operational environment. These factors, by and large, will determine the tactics to be used, the profiles to be flown, and perhaps the success or failure of a given mission. A potential problem area identified during this session was that of operator workload. It was suggested that this might be alleviated by going from a one- to a two-seat mode of operation.

Session II - System Requirements

The second session of the Workshop was chaired by Mr. Wayne Martin, Visual Display Systems Branch, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. The objective of this session was "to acquaint attendees

with the process that the design engineer goes through to evolve a system that will meet the mission/doctrinal requirements." A total of six speakers made presentations during this session. They were Maj. Jerry Armstrong, F-16 SPO, Wright-Patterson Air Force Base, Ohio; Mr. Harry Waruszewski, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio; Dr. Roy Frick; Col Clarence Patnode, TADS/PNVS Project Manager, St. Louis, Missouri; Mr. Joseph Colombo; and Lt Thomas Mitchell, Naval Air Development Center, Warminster, Pennsylvania.

Maj Armstrong discussed a study recently completed by his office to define expanded capability options for the F-16 aircraft. The objective of the study was to identify candidate technologies and development programs that have potential F-16 applications; to identify development voids; to assess options for F-16 missions; and to recommend initiatives to expand the capability of the F-16. He stated that in looking at potential integration impacts of such systems or subsystems as JTIDS, advanced sensors such as FLIR and TV tracking/laser designation pods, E-O weapons, etc., it quickly became evident that display options would play an integral part in the expanded capability definition. Maj Armstrong concluded by stating that the R&D community and the system acquisition community must work hand-in-hand to anticipate requirements while always considering the real world limitations of technology and aircraft integration.

Mr. Waruszewski talked about display system requirements and their specification. Major points made in his presentation were that display system requirements: (1) should be GFE rather than CFE and that we should be writing the requirements into engineering specs and/or procurement specs,

and; (2) are derived either through a Required Operational Capability (ROC), a General Operational Requirement (GOR) or a Statement of Need (SON) and that current management philosophy is to either let the contractors generate requirements or give the contractors the specs and have them bid on them. (Mr. Waruszewski's presentation was not available for inclusion in the proceedings.)

Dr. Frick's presentation focused on system analysis, the process used to translate mission requirements to system requirements. This process takes the mission requirements and expresses them in mathematical terms, i.e., a system model is derived. He listed five levels of comparison (analysis and modeling), each of which requires the engineer to have an appreciation of the requirements for an effective air-to-ground system and the influence of mission details on the model. Once this is done, representation of a system can be made in the model. He then pointed out that the analysis methodology is built on the representation of different phases of the mission - base operations, cruise, penetration, and terminal target attack. Dr. Frick also discussed how the mission requirements were translated into system requirements for one vs two-seat target acquisition/weapon delivery.

Col Patnode discussed the role of the project manager (PM) in the evolution of the TADS/PNVS displays. He prefaced his presentation by stating that at the point where a technically feasible system has been identified to satisfy a given mission requirement, thus resulting in a requirements document, the PM begins preparing a detailed development plan for a generic system to meet the user's requirements. In doing so, he goes through a series of development milestones. These include: (1) the development and release to industry of an RFP that details the required generic system in a specification; (2) responses to the RFP and selection of a contractor(s) for the development effort; (3) the

contractor develops system characteristics from which they generate their own specifications to meet the requirements of the government specifications, and; (4) test and evaluation of the developed hardware. In his presentation, Col Patnode went through each of the development milestones as they related to the evolution of the TADS/PNVS display systems.

Mr. Colombo again talked about the F-14 CILOP study, however, this time he emphasized the controls and displays subsystems. He stated that the needs which help define the controls and displays requirements include operational and system needs. Operational needs include multiple targets, complex raid structures, identification requirements, ACM (air combat maneuvering) quick reaction, mission completion, ECM environment, and fleet interoperability. System needs include data availability, processing capability, redundancy, flexibility, data formatting, operator workload, and weapon requirements. He stated that display recommendations for CILOP consist of an integrated controls and displays subsystem based on the Airborne Integrated Display System (AIDS) concept which includes redundant programmable digital processors, multifunction displays, a dawn-to-dusk TV identification system, and dual cockpit helmet mounted sight (HMS) systems.

Lt Mitchell's presentation dealt with the concept definition of a night vision system for USMC transport helicopters. In his presentation, Lt Mitchell touched on four areas: (1) night vision system requirements for transport helicopters in amphibious operations; (2) description of the analysis leading to concept definition; (3) identification of system options, and; (4) selection of options.

In reviewing the papers presented during this Session, the major theme seems to be that, in order to translate the mission/doctrine requirements into

system specifications, the requirements must be easily understood by the design engineer and readily translated into design specifications that can be met.

Session III - Human Factors

Session III dealt with the topic of human factors and was chaired by Dr. John Reising of the Air Force's Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. The objective of this session was "to delineate those visual human performance factors which must be borne in mind during the development cycle of a given system." Four speakers made presentations during this session. They were Dr. Frank Holly, U.S. Army Aeromedical Research Laboratory, Ft. Rucker, Alabama; Dr. Keith Burnette, Bunker-Ramo Corporation; Dr. Harry Snyder, Virginia Polytechnic Institute and State University; and Dr. H. Lee Task, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. (Mr. Walter Carel, Hughes Aircraft Company, Culver City, California was unable to make his scheduled presentation due to illness. However, he was kind enough to send a copy of the paper he was scheduled to present to include in the proceedings.)

Dr. Holly's presentation covered the topic of psychophysical considerations in display design. In his presentation, he discussed some of those psychophysical factors which receive less frequent attention but which nevertheless have an important impact upon display design. The factors included: (1) effect of surround; (2) monocular vs binocular acuity; (3) effect of target size upon perceived velocity, and (4) multiple imaging produced by saccadic eye movements.

Dr. Burnette's presentation dealt with the effect of glare on display image luminance requirements. Based on an extensive analysis of the display and vision research literature, an empirical equation which describes the ideal luminance requirements was developed. Additionally, techniques for

describing the changes in luminance requirements made necessary when either the display or the viewing conditions are no longer ideal were developed. Dr. Burnette then discussed how display image legibility is influenced by the presence of glare-inducing illumination levels within the observer's field of view. He also proposed a model for predicting the increase in the ideal display image luminance requirements when discrete and/or distributed glare sources are present.

Dr. Snyder's presentation dealt with the topic of image quality metrics and a discussion of the various figures of merit (FOM) used in measuring image quality, e.g., MTFA, SNRD, etc. In addition to pointing out the various measures that are available, Dr. Snyder stated that we need to specify them in photometric terms. Dr. Snyder also stated that the ideal display should have a 40 db, high contrast signal. (Dr. Snyder's presentation was not available for inclusion in the proceedings.)

Dr. Task's presentation focused on his past efforts to correlate the various figures of merits used in measuring display image quality and on his current efforts in sensor/display parameter modeling. He stated that the goal of his modeling effort is to define what has to be done in order to satisfy the requirements for advanced displays for FLIR or TV systems. He then presented a brief description of his model and the relevant parameters used. (Unfortunately, Dr. Task's presentation was not available for inclusion in the proceedings.)

In reviewing the presentations given during this Session, it is unfortunate that the limitations of the human operator are not directly addressed. What is presented are those display factors that relate to the displays themselves - what luminance is required, the measures of image quality, etc., but nowhere is there presented data relating to the interaction between human capabilities/

abilities and display parameters. It is apparent that there is a need to show this relationship in a more explicit manner. Work presently being conducted at AMRL is expected to more clearly demonstrate the impact of the filtering properties of individual operators' visual systems on the detection and recognition of target imagery.

Session IV - Discussion of Sessions I, II, and III

Session IV was the first of the discussion forums and was moderated by Capt Robert Verona, U.S. Army Aeromedical Research Laboratory, Ft. Rucker, Alabama. The objective of this session was "to determine how the topics covered in Sessions I, II and III interrelate and what impact each has upon the other and upon advanced display requirements." The discussion forum emphasized the need to automate weapon system functions in order to reduce workload during critical mission segments. System automation (i.e., flight control, autohover) was desired to free the pilot for the performance of other tasks. Subsystem automation was discussed in great detail. Functions identified for automation were: sensor tracking, handoff between target acquisition and weapon sensors, display controls, and target acquisition sensor imagery cueing (perhaps to the extent of target recognition). Questions were raised concerning the availability of proven technology, cost, redundancy/fail soft requirements, and the need to retain the human as the decision-maker. Great concern was raised about attempting close air support weapon delivery on the basis of a symbolic display generated by a totally automated target recognition subsystem. Problem areas surfaced included IFF, countermeasures (field expedient signature changes and decoys), and the need to differentiate between "fresh" and previously attacked targets.

Areas were surfaced for increased emphasis. Full system integration and

simulation was seen to be needed for better understanding of capabilities and limitations. More extensive field trials were projected to be required for the iterative refinement of system specifications. A general acceleration in display technology development was desired to increase the display modality options available to the program manager.

A general conclusion from this session is that there is an evident breakdown in continuity of approach between the requirements and technology areas of the community. More specific, valid scenarios, including operator tasking, must be available in order to promulgate subsystem specifications which accurately reflect both the requirements to be satisfied and the available technology. (An approach being followed in the Air Force to alleviate the effects of this problem is the circulation of draft SOWs to industry for early review and critique).

Session V - Terminology

Session V was a rather brief session chaired by Dr. H. Lee Task of the Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. The objective of this session was "to establish agreement as to the interpretation of terms being used within the sensor/display community." Dr. Task wished to establish lines of communication between individuals who are interested in developing a standardized set of terms, definitions, and measurement procedures for quantifying the performance of E-O sensors and displays. The need for such a commonality of understanding was illustrated by Dr. Task in a comparison of definitions of the same terms taken from various existing standards. This comparison showed that many of the definitions were not in accord with one another. Dr. Task then presented and discussed the approach he intended to use,

presented a partial listing of some of the terms which required common interpretation, and handed out a questionnaire. A copy of the questionnaire is included in the proceedings.

Session VI - Sensor/Display State-of-the-Art

Session VI covered the area of sensor/display state-of-the-art (SOA) and was co-chaired by Capt David Hake, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio and Dr. Elliott Schlam, U.S. Army Electronics R&D Command, Ft. Monmouth, New Jersey. The objective of this session was "to acquaint attendees with current state-of-the-art in sensors and displays." This session was divided into two parts - the first half being devoted to sensors and the second half to displays. Besides Capt Hake, other speakers in the sensor area included Mr. Ronald Siwecki, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio; Mr. Andy Grandjean, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio; and Mr. Stuart Layman, Night Vision and Electro-Optics Laboratory, Ft. Belvoir, Virginia. Speakers for the display area in addition to Dr. Schlam included Mr. Harry Waruszewski, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio; Mr. John Mysing, Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio; Mr. James Brindle, Night Vision and Electro-Optics Laboratory, Ft. Belvoir, Virginia; and Mr. Steve Kay, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

Capt Hake, in opening the sensor portion of this session, stressed the fact that, although the common module FLIR has increased our effectiveness, the scenarios for the 1980's are growing more demanding and the increased

capabilities in our adversaries' offensive and defensive weaponry are driving FLIR sensor requirements towards: (1) greater detection/recognition ranges; (2) better adverse weather capability; (3) reduced operator workload, and; (4) decreased sensor size, weight and power. Capt Hake then discussed the approach that is being used to meet these requirements.

Mr. Siwecki's presentation dealt with the common module FLIR as it applies to the PAVE TACK system. He described the system and some of the results obtained from the acceptance testing and from some of the flight tests. (Due to the classified nature of the information, Mr. Siwecki's presentation has not been included in the proceedings in order that this document be kept unclassified.)

Mr. Grandjean's presentation dealt with the FLIR Technology Demonstration (FTD) program being conducted by his organization (under contract) to develop a concept for the next generation FLIR sensor. He indicated that mission analysis and concept formulation studies conducted during Phase I of this effort were used to develop the design and establish the operational requirements for the next generation FLIR sensor. He also pointed out that a limited display study was performed as part of the concept formulation study. He stated that the study dealt with how existing CRT technology, or advanced display technology, could satisfy the sensor/operator interface requirements in an aircraft such as the F-16. Also, as part of the concept formulation task, two concepts were posited in connection with the display problem - a liquid crystal display (LCD) and a CRT virtual image display.

Mr. Layman discussed two programs currently being pursued to develop high performance second generation FLIR systems for the Army. The first is the Advanced Tactical (ATAC) FLIR and the second is the High Sensitivity Tank FLIR (HISTAF). The ATAC FLIR is a technology demonstrator for airborne applications

incorporating a CCD processed Si:In focal plane assembly operating in the 3-5u region. Automatic image processing is included in this system. The HISTAF system is being developed for future combat vehicle applications and incorporates a high density focal plane using 8-12u PV HgCdTe detectors with CCD processing on the focal plane. The emphasis in this program is on high sensitivity for poor weather operation and degraded atmosphere penetration.

Dr. Schlam opened the display portion of this session by focusing on three areas - technology management, display requirements, and display devices. In the technology management area, he stated that: (1) the system specifications must address the man/machine interface and must recognize the importance of the display; (2) we must tell the contractor what is expected of him with regard to the man/machine interface; and (3) we must require the contractor to design for technology insertion, i.e., support 6.3A efforts. In delineating the display requirements, we must keep in mind: (1) the specifications; (2) system configuration, and; (3) functional configuration. In the area of display devices, he discussed CRT and flat panel displays.

Mr. Waruszewski's presentation focused on a historical look at CRTs in the Air Force. Utilizing photos of the various displays, he discussed the various panel mounted and heads up display (HUD) devices that have been and are currently in the Air Force's inventory.

Dr. Schlam's presentation centered on direct view solid state displays. In particular, he discussed technology developments in three areas - thin film transistor electroluminescent (TFT-EL) displays, liquid crystal displays (LCD), and light emitting diode (LED) displays. Within each of these flat panel display areas, he described the construction and operating (performance) characteristics of each and listed some of their advantages as well as limitations. He also demonstrated an imaging EL display.

Mr. Mysing's presentation focused on HUD's with emphasis on the application of diffraction optical elements (DOE) to these displays. Unfortunately, Mr. Mysing's presentation is not available for publication.

Mr. Brindle's presentation dealt with the area of helmet mounted displays (HMDs). After giving a brief description of the concept, Mr. Brindle gave an overview of the state-of-the-art in this area. This overview was then followed by a discussion of the major development thrusts for HMDs.

Mr. Kay's presentation centered on the displays used with the PAVE TACK sensor. In particular, he focused on the virutal image display (VID) found in the rear seat of the F-4C aircraft. He indicated that the main drivers for a VID-type display were lack of panel space, longer ranges, larger displays, and tracking. Mr. Kay's presentation is not available.

In reviewing the papers presented in this Session, the major thrusts in sensor development is towards increasing detection/recognition ranges, providing higher resolution, and usability during adverse weather conditions. In the display area, although developments in the area of solid state devices have made great strides, it is apparent that the CRT device will continue to be the principal display device for the immediate future.

Session VII - Open Executive Session

The final, yet most important, session of the Workshop was an open executive session jointly chaired by the tri-service representatives to the Display Working Group - Mr. Wayne Martin (Air Force), Mr. James Brindle (Army), and Mr. William Mulley (Navy). The objective of this session was "to assess what had transpired at the Workshop and to generate recommendations regarding future research efforts, future development efforts, and future activities in the

display area." As was the case for Session IV, the discussions and dialogue which took place during this session were recorded and transcribed and can be found in the proceedings section. The following issues received individual discussion:

1. Display development efforts should be evolutionary in nature, an iterative process, with options for technology insertion.

2. There is insufficient user/developer/designer interaction.

3. There is a gap between display technology base (6.2) and system development (6.4), which must be filled by 6.3A work.

4. We don't understand the man-machine interface as related to the mission requirements sufficiently well to properly spec display needs (e.g. resolution, size, interaction, cuing, tuning).

5. There is a lack of concepts for future systems based on anticipated military needs to drive the technology base.

6. There is need for "real world" analysis, study, and flight test simulation of system/device configurations based on user needs.

7. There is a void in the application of state-of-the-art technology to systems development because of the lack of 6.3A funding.

8. We don't use (or have not developed) systems integration concepts/tools well enough to properly trade-off between subsystem capabilities.

9. There is insufficient attention spent on displays except when they appear not to do their job.

10. The display requirements necessary to perform specific tasks (e.g., navigation, pilotage, target acquisition, weapon delivery) have not been sufficiently defined; and that definition is not a simple process (see #6).

11. It is apparent that display technology and display systems development across the services is being pursued in a non-duplicative way, and that in fact, there are voids where added emphasis is required.

12. Common and valid measures of operator workload with regard to displays and other aircraft subsystems are needed.

13. We need standardized display/sensor measurement techniques.

SESSION I - MISSION/DOCTRINE REQUIREMENTS

TRI-SERVICE DISPLAY WORKSHOP

MISSION/DOCTRINAL REQUIREMENTS

DR. ROY FRICK
AERONAUTICAL SYSTEMS DIVISION
ASD/XROL
WPAFB, OH 45433

Session I - Mission/Doctrinal Requirements

How mission/doctrinal requirements are derived and what these requirements are.

Dr. Roy K. Frick
Aeronautical Systems Division (XRO)
WPAFB, OH 45433

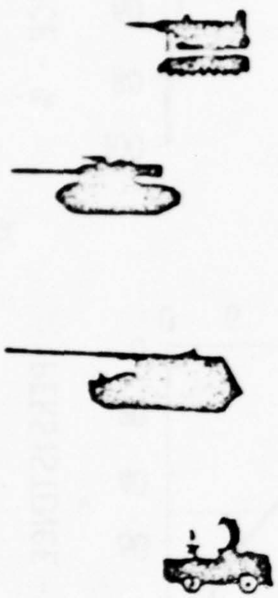
In this session we will examine the nature of the mission and how requirements and doctrine are derived.

In the European theatre, mission requirements are the most severe as shown on the first chart. Typical target arrays and defenses are such that target acquisition and aircraft survivability are of prime concern. The weather in central Europe is characterized by low ceilings a significant portion of the time. To be successful in this environment requires an effective tactical Air Force which can achieve increased target kills per sortie and increased sorties per day, i.e. improvements in productivity over what we have today.

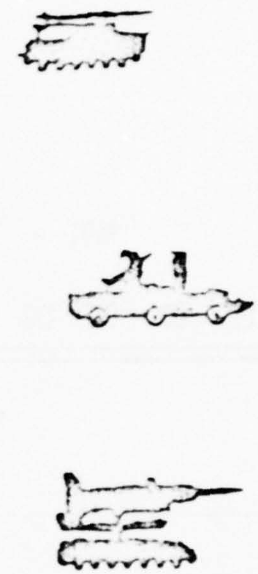
ASD has sponsored a study on one versus two seat target acquisition/weapon delivery. The latter charts summarize a portion of this study, in particular how mission and doctrinal considerations are derived.

OFFENSIVE AIR SUPPORT

WE CAN EXPECT



- FIGHT OUTNUMBERED / OUTGUNNED
- MASSIVE AIR OFFENSIVE
- HEAVY MOBILE AIR DEFENSES
- 24 HOUR BATTLE/ALL WEATHER
- FLUID/FAST MOVING ARMORED FORMATIONS
- EXTENSIVE USE OF EW
- ECHELONS IN DEPTH



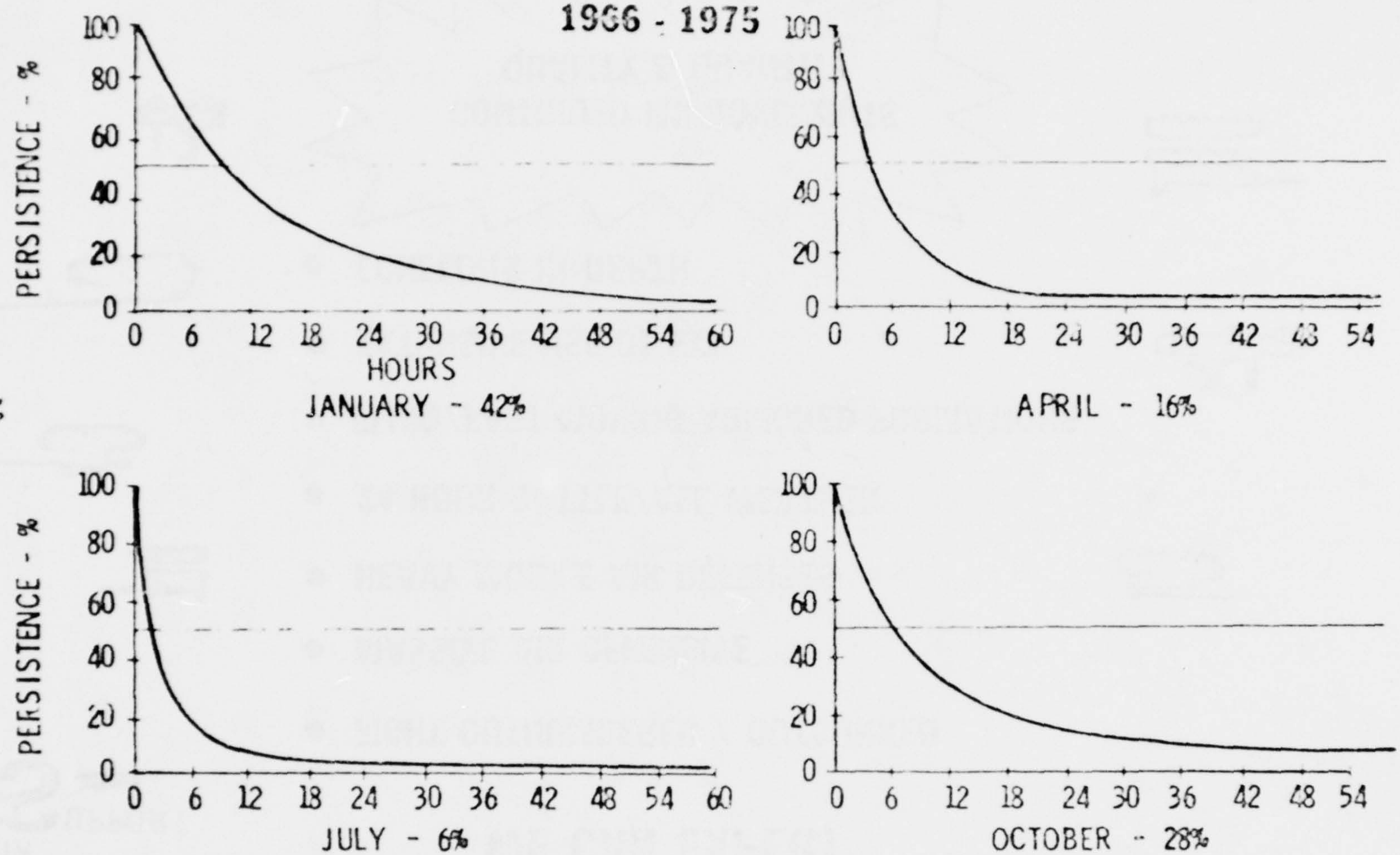
CONTINUED IMPROVEMENTS
QUALITY & QUANTITY

DEFENSE AIR SUPPORT

PERSISTENCE OF CEILING BELOW 3000 FEET

KITZENGEN, GERMANY

1966 - 1975



	SOURCE: ETAC - ASD/WE	WKC 2/77

OFFENSIVE AIR SUPPORT

WHAT'S IMPORTANT

PRODUCTIVITY

- INCREASED KILLS/SORTIE
  - ACQUISITION
  - ACCURACY AND QUICK RESPONSE
  - ARMAMENT
  - COMMUNICATIONS
  - SURVIVABILITY

HIGH SUSTAINED KILL RATES

- INCREASED SORTIES/UE/DAY
  - BASE AND A/C SURVIVABILITY
  - SORTIE RATES
  - MAINTENANCE
  - LOGISTICS
  - CREW FACTORS

RESPOND IN QUANTITY AT THE RIGHT TIME AND PLACE

INTRODUCTION

ONE VERSUS TWO SEAT

TARGET ACQUISITION/WEAPON DELIVERY

STUDY PERIOD: MAY - DECEMBER 1978

SPONSOR: ASD/XROL

CONTRACTOR: STEPHEN HOWE (CONSULTANTS) LTD

STUDY PURPOSE

The study is aimed at identifying how technology might alleviate crew workload during target acquisition and weapon delivery. The particular application is air-to-ground operations in Europe. Bad weather is frequent in this NATO theatre and aircraft systems need to be effective in this environment. One and two seat systems may be appropriate for differing roles. The study will focus attention on the boundary between these two alternatives.

STUDY PURPOSE

TO IDENTIFY HOW TECHNOLOGY CAN HELP:

- ALLEVIATE CREW WORKLOAD
- IN ADVERSE EUROPEAN WEATHER, AT NIGHT
- PUSH THE BOUNDARY BETWEEN 1 AND 2 SEAT OPERATIONS

STUDY SCOPE

The scope of the study can be stated as follows:

1) The theatre of operations is central Europe with the appropriate environmental factors considered, e.g. EW intensity. The implications of operations in both the 4th Allied Tactical Air Force (ATAF) and 2 ATAF areas has been considered.

2) The weather conditions are adverse; bad visibility and low cloud. The aircraft system must be effective under these conditions.

3) No particular aircraft has been considered, but a generic, late 1970s, ground attack system has been devised.

4) The theatre scenario assumes the use of conventional weapons only.

5) The operational time scale under consideration is the late 1980s.

STUDY SCOPE

- CENTRAL EUROPEAN OPERATIONAL THEATRE (2 AND 4 ATAF AREAS)
- BASELINE CONDITIONS
  - CEILING 500 FT
  - VISIBILITY 2.5 MILES
  - PRECIPITATION
  - 1/4 MOONLIGHT
- CONVENTIONAL WEAPONS
- LATE 1980's OPERATIONS

STUDY CONSTRAINTS

The study is concerned with the terminal phase of an air-to-ground engagement. We have covered three mission types; close air support (CAS), battlefield air interdiction (BAI) and deep strike. The technology applied to the baseline system is representative of the late 1970s. No specific aircraft is considered; a generic vehicle drawing from the current inventory is defined.

The measures used within the study relate to crew workload. It is the application of technology to this aspect of total effectiveness that we have studied. Other collateral aspects do not form part of the study, e.g. weight, cost, survivability.

STUDY CONSTRAINTS

- AIR-TO-GROUND: TERMINAL PHASE
- LATE 1970'S ON-BOARD SYSTEMS AND TECHNOLOGIES BASELINE
- WORKLOAD-RELATED EFFECTIVENESS

NATURAL ENVIRONMENT

The central European weather pattern is generally one of frequent occurrence of low cloud and fog in winter and of thunderstorms and haze in summer. Air-to-ground operations over a 24-hour period are thus likely to be accompanied by cloud and poor visibility. Typically the 6–8 eighths cloud/2½ mile visibility/precipitation condition is met some 30% during daylight hours. Visibility at night is a function of many factors; cloud base, phase of moon, precipitation, contrast of object, etc.

The effect on acquisition sensors is felt most by TV (unless given low light capability) where visual contrast is critical to detection, and subsequent classification and tracking. By the same token, without an effective night/adverse weather forward-looking sensor, the aircraft would have to fly higher with the attendant increase in vulnerability. This points to IR and radar sensors to extend operations into these more difficult conditions.

Although adverse weather and night may force missions to be conducted from a greater height, the ground defenses are not themselves unaffected. In particular, those weapon systems using visual, or visually aided, acquisition would suffer most.

TERRAIN – N GERMANY

The N German plain forms part of the 4 ATAF operational region. The "flexible response" doctrine of NATO implies that USAFE aircraft may be in operation in this northern region. Recognition of this possibility is made within the study.

The very flat countryside presents its own problems; navigation cues are less apparent and man-made obstacles more significant. The demands on the pilot, although different to the 2ATAF region, are likely to stress him equally.

We have used a masking angle of $\frac{1}{2}^{o}$ in the study to represent the northern area. As a consequence, very low level penetration profiles are likely. This is reflected in the terminal phase as well. LOS at 150 ft is typically 17 000 ft which allows defences significant time to respond to the threat of aircraft.

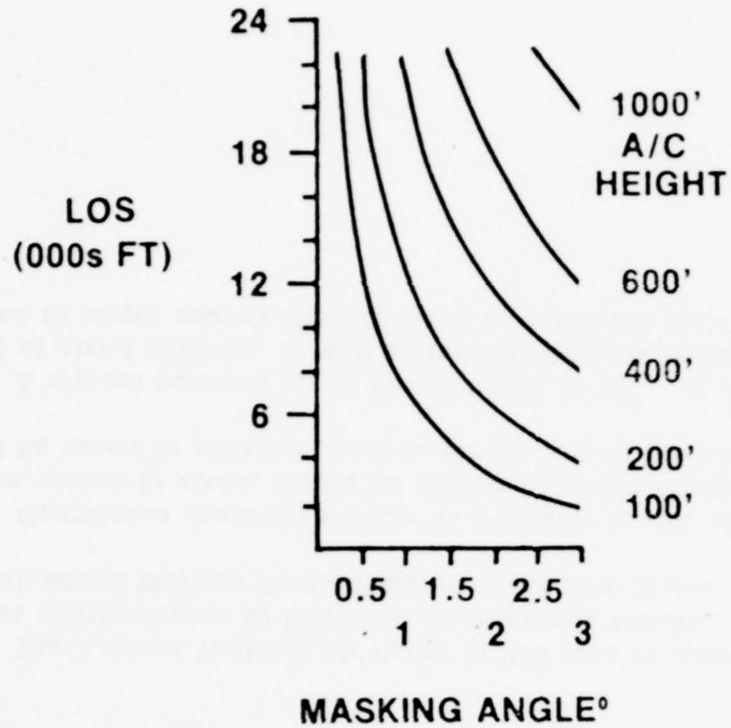
TERRAIN – S GERMANY

The 2 Allied Tactical Air Force (ATAF) area of operations is in S Germany. The forward area is characterised by hilly and mountainous terrain. Various locations form natural funnels through which Warsaw Pact advances could take place; the Fulda gap is one.

Operations could take place at a greater height AGL then in the lowland areas. Defenses, unless optimally sited, would be affected by terrain masking. Advantage of the same factor could be taken by allied aircraft in the routing of the penetration phase.

A typical masking angle for this area is $2\frac{1}{2}^{\circ}$. It corresponds, at 150 ft, to a line of sight (LOS) of about 3500 ft. At 450 kn this distance is traversed in under 5s. The impact of these figures in target search effectiveness is one topic for analysis.

MASKING VS LOS

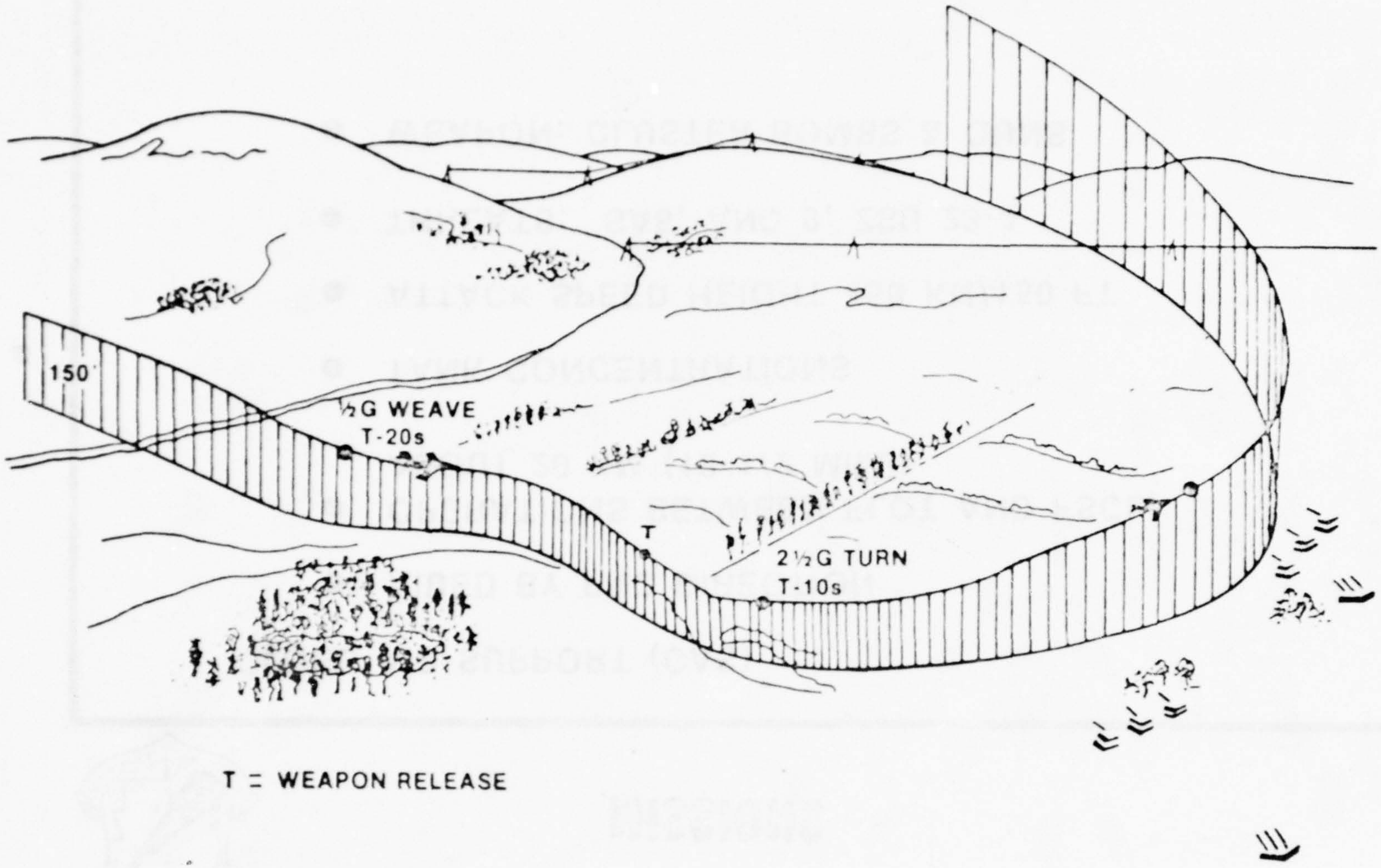


MISSIONS

CLOSE AIR SUPPORT (CAS)

- AIDED BY FAC DIRECTION
- OPERATIONS BETWEEN FLOT AND FSCL; ABOUT 20 KM (12 1/2 MILE)
- TANK CONCENTRATIONS
- ATTACK SPEED HEIGHT 450 KN/150 FT
- THREATS: SA6, AND 9, ZSU 23-4
- WEAPON: CLUSTER BOMBS & GUNS

CLOSE AIR SUPPORT (CAS)



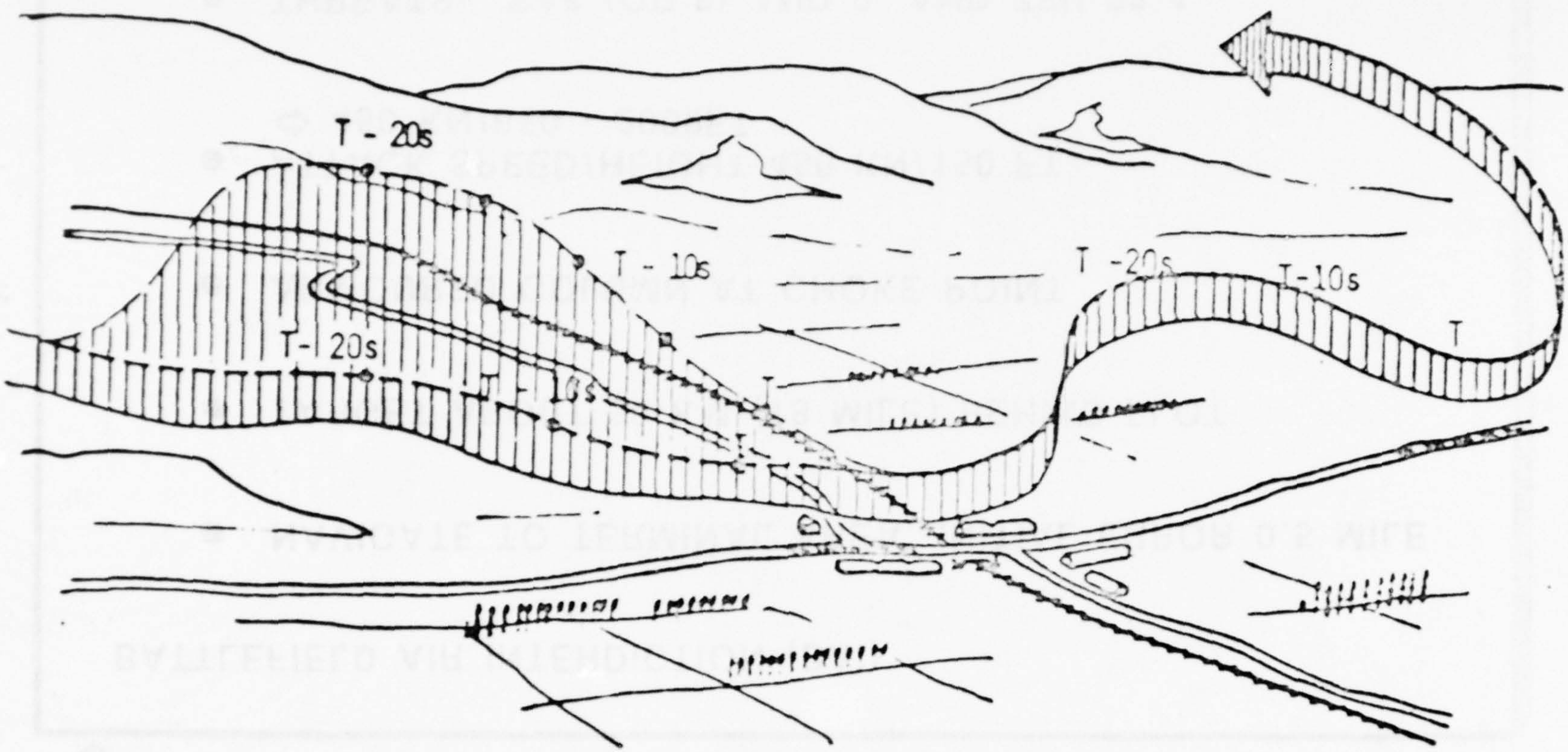
T = WEAPON RELEASE

MISSIONS

BATTLEFIELD AIR INTERDICTION (BAI)

- NAVIGATE TO TERMINAL AREA, INITIAL ERROR 0.5 MILE
- TARGET ABOUT 30 KM (18 MILE) BEHIND FLOT
- ARMOURED COLUMN AT CHOKE POINT
- ATTACK SPEED/HEIGHT 450 KN/150 FT
  ⇨ 450 KN/650 - 2000FT
- THREATS: SA6 (OR 8) AND 9, AND ZSU 23-4
- WEAPON: CLUSTER BOMBS AND AGM

BATTLEFIELD AIR INTERDICTION (BAI)



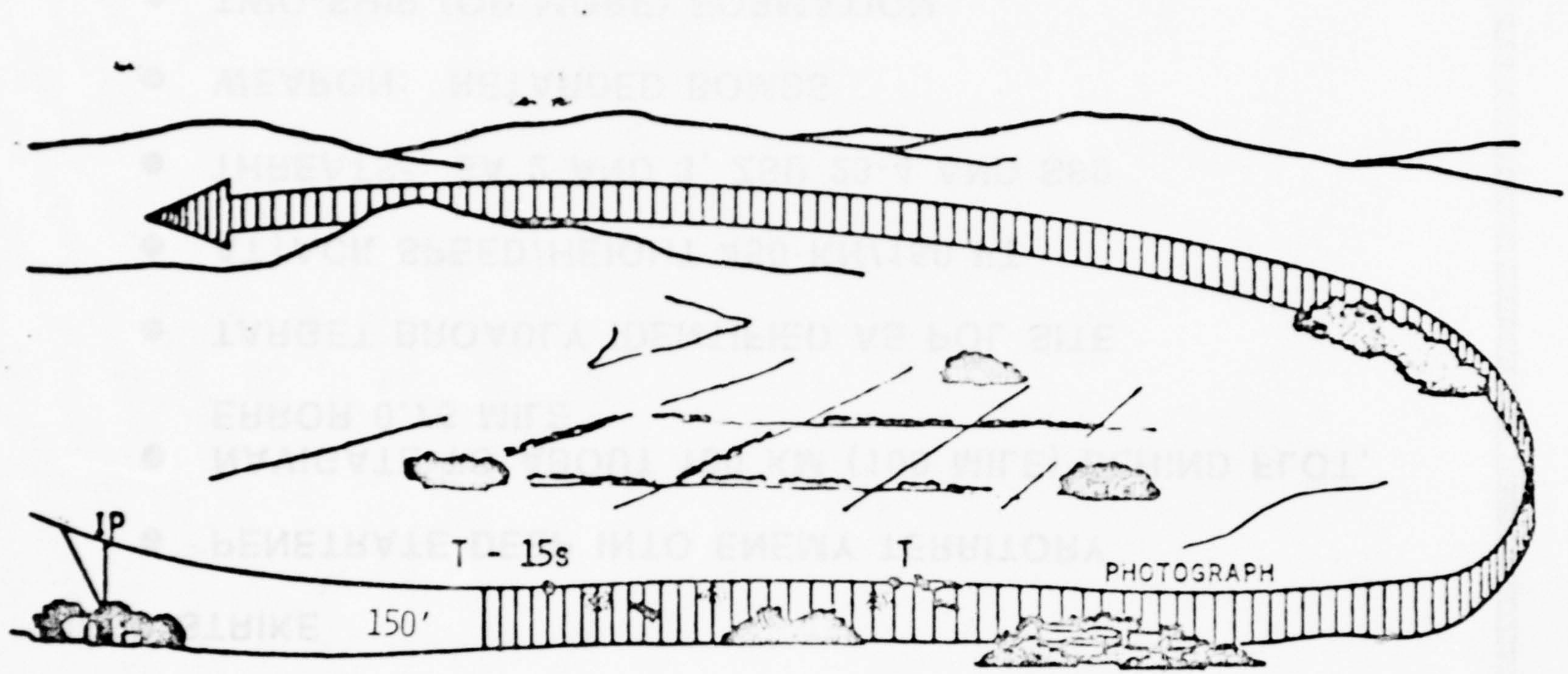
T = WEAPON RELEASE

MISSIONS

DEEP STRIKE

- PENETRATE DEEP INTO ENEMY TERRITORY
- NAVIGATE TO ABOUT 160 KM (100 MILE) BEHIND FLOT, ERROR 0.75 MILE
- TARGET BROADLY IDENTIFIED AS POL SITE
- ATTACK SPEED/HEIGHT 450 KN/150 FT
- THREATS: SA 2 AND 3, ZSU 23-4 AND S60
- WEAPON: RETARDED BOMBS
- TWO-SHIP (OR MORE) FORMATION

DEEP STRIKE



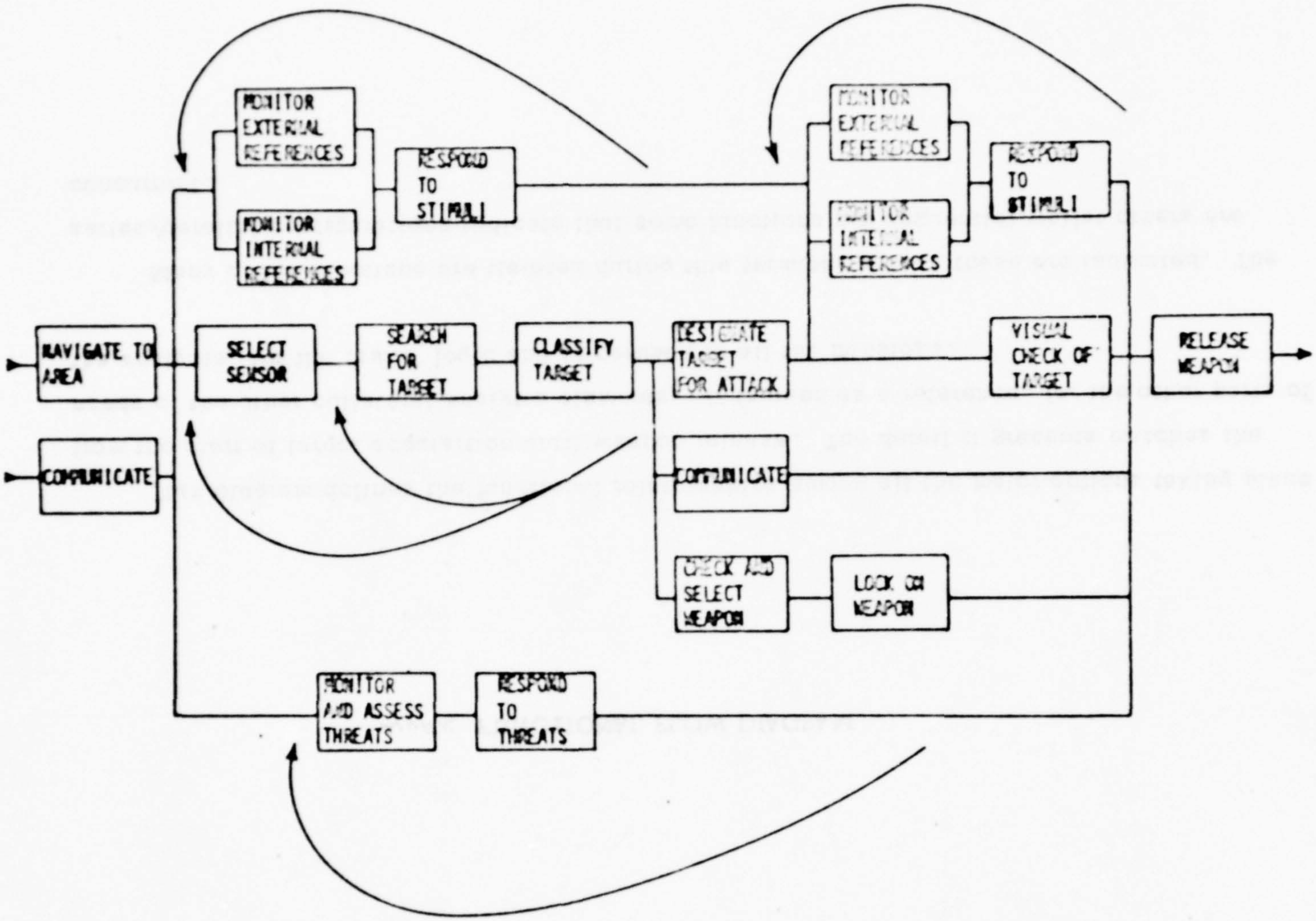
T = WEAPON RELEASE

WORK FUNCTIONAL FLOW DIAGRAM

This diagram defines the functional relationships among all the major actions taking place from the start of target acquisition until weapon release. The detail it presents matches the needs of the other collateral analytic elements. It is used as a reference, for the other parts of the analysis, for the tasks' logic and is common to all the missions.

Many of the functions are iterated during this terminal phase, these are indicated. The series/parallel configurations indicate that some functions are sequential whilst others are concurrent.

WORK FUNCTIONAL FLOW DIAGRAM



MISSION/DOCTRINAL REQUIREMENTS

Lt Col Cliff Ohlenburger, USA
U. S. Army Aviation Center

I. Introduction

TRADOC is the Army's principal combat developer and many requirements are generated within the Combat Developments Directorates at the many schools and centers. On the other hand many other requirements are generated outside TRADOC as will be discussed later. However, all these requirements eventually find their way into the TRADOC family for processing. Those which are considered worthy of consideration are incorporated into existing requirements or they are developed into the proper form according to the life cycle management model and processed.

The U.S. Army Aviation Center (USAAVNC) at Ft. Rucker, Alabama has propencency for aviation related night vision systems. With that propencency, Ft. Rucker speaks for all requirements in that area.

Major General Marrymzu, the Army Aviation Center's commander, is the TRADOC community's aviation advisor. As our new commander, Major General Marrymzu has provided new guidance and direction to Army Aviation related Combat Developments and the Aviation Center will be involved in <u>all</u> aspects of aviation.

II. Requirements Generation

The next two slides will mention a few ways in which requirements are generated.

A requirements document can be initiated by anyone in the field who sees a need or feels they have a solution to existing shortcomings. Many field requirements are generated as a result of field exercises such as REFORGER, normal unit training, or unique unit situations such as found in Alaska or the Canal Zone.

The Aviation Center maintains up-to-date threat information as it relates to Army Aviation. This threat information is kept current for both the near term and projected situation. As new threats are identified, concepts and doctrine are developed to combat them. In some cases, only changes in tactics may be required, however, new equipment capability may be required to defeat them.

Guidance and HQDA studies often result in new requirements.

There are many known deficiencies maintained on the books, so to speak, and as technology allows, these requirements find their way into a requirements document.

We have many requirements documents which date back to the early '60s and '70s. These documents must be periodically reviewed and updated. These updates and reviews often identify areas of concern and the appropriate document is changed or eliminated.

One of the major documents which initiates activity both on the part of industry and within DARCOM is the Science and Technology Objectives Guides (STOG). This document is the key to maintaining a military technology base at the Laboratories; it is the principal document for formulation and prioritization of user-oriented requirements for the mid-to-long-range planning periods.

The Battlefield Development Plan is a document to focus, prioritize, and integrate TRADOC efforts in material and training developments force structure, concepts and doctrine and a vehicle to provide TRADOC views on major issues to DA and others.

Mission Area Analysis (MAA) is to identify force deficiencies in, and opportunities to enhance, our war fighting capabilities.

Mission Element Need Statement (MENS) identifies the mission area and states the need in terms of the mission element task to be performed.

Technological breakthroughs can accelerate the material developments process and/or result in a requirements document which results in a material development.

Special reviews and studies such as AAPR, AVNEC and the current Division 86 efforts often result in at least a long list of deficiencies which find their way into a requirements document.

The Product Improvement Program (PIP) is a process by which Army Materiel is modified to meet user requirements, meet approved performance specifications, correct equipment deficiencies or improve RAM characteristics.

TRADOC has a Concept Evaluation Program which test/evaluates new or modified concepts which could improve doctrine, tactics, training, and hardware. This program is a quick look and see to determine if a concept is worth continuing. Additionally, it provides important information and understanding required to write a useful requirements document.

III. Life Cycle Management

The Life Cycle Management model is the guide to material developments which the DoD family is required to use as guideline. As requirements are generated, as discussed earlier, they will usually take the form of either a Letter of Agreement (LOA), Letter Requirements (LR) or Required Operational Capability (ROC). As we all know, this process is time consuming and we are all obligated to do all we can to accelerate material developments to prevent the fielding of equipment which is obsolete before it reaches the troops.

IV. Combat Development Process (CDP)

Describes how the Army decides what to buy and tells you what you should be doing at any given time in order to make your appropriate contribution to the major material acquisition decisions.

The document is dated August 1978 and was updated in February 1979.

This is the first time that the entire POM/Budget cycle major milestones (time sequenced) have been put together in one document.

It contains explanation of the CD process, master planning schedules, individual program planning schedules, and monthly planning schedules.

It is designed to provide all TRADOC schools and centers with the proper tools to directly influence the budget and in effect, shape the future Army.

V. Army Aviation in the High Threat Environment

First I will discuss requirements that are general in nature to provide a basic understanding of conditions under which Army Aviation must operatre. Additionally, I will discuss some broad capabilities and requirements which are not specifically aircraft-type sensitive. Secondly, I will list a few requirements documents in which the specific characteristics are contained.

Army Aviation in the high threat environment can no longer afford to be a daytime aviation capability, we must be ready to accomplish our mission on a twenty four hour basis.

We cannot accept a wide difference in capabilities between day and night mission performance. Our performance must be near equal both day and night.

The threat to Army Aviation in the European environment is probably the greatest, however, we cannot expect to fight anywhere in the world and find less of a threat than found at the end of the Southeast Asia conflict. As you well know, towards the end of that fighting, sophisticated anti-aircraft weaponry forced Army Aviation into the terrain flight environment. The only difference that can be expected in any future conflict will be in quantity of air defense, not capability. Aircraft survivability against the known threat can be acceptable using terrain flight techniques combined with aircraft survivability equipment and clearer target acquisition capabilities. The terrain flight environment is explained as follows:

Contour flight: maintaining a constant altitude which clears obstructions.

Low Level: following the curve of the earth and using only sufficient altitude to clear obstructions to flight.

Nap-of-the-Earth(NOE): flying as low to ground as possible, maintaining rotor clearance from obstacles.

The closer to the FEBA the lower an Army aircraft must fly to survive. Flying forward from the Division rear area toward the front, you will progressively move from contour flight to NOE, the latter of which is the most demanding on the aircraft crew and installed systems. NOE flight will see rapid accelerations from 0 - 80 knots, periods of hover in and out of ground effect, rapid changes in direction with turn angles in excess of 60°.

Army aviation must operate in periods of reduced visibility on a 24 hour basis. Obstructions to visibility both natural, such as fog, rain, snow, etc., and those man-made obstructions such as smoke, obscurants resulting from battle. Intensive battle can quickly turn a clear day with good vivibility and a few clouds into a dark, cloudy day with visibility restrictions to as low as 1/4 mile. History verifies this. Any battle we can expect will result in destruction which will leave many buildings and equipment burning, smoking and exploding in the battle area.

Navigation and target acquisition must be accomplished in this dirty environment insuring that aviation assets are at the right place at the right time and can acquire and engage targets at the maximum ranges of the weapon systems.

Survivability will be dependent on minimizing exposure time while navigating, acquiring, and engaging targets. This may require scanning the battle area quickly, allowing the aircraft to remask, then review stored information for targets. Another alternative may be to provide a system which places the pilot or observer eyes above the rotor plane (Mast mounted sight).

It is important that the designer of any aircraft system, such as night vision equipment, keep in his mind that operation of that system should complement survivability.

Where practical, we must strive for passive systems to minimize detection.

The concept of modularity should be addressed in order to take advantage of economics in numbers where different sensor packages may be composed of some common components. Additionally, technology vs. weight may not allow some Army aircraft to carry both a day and night sensor package, therefore the commander must be able to tailor his aircraft to the mission. Ideally, the system sensor package would have both a day/night capability, be lightweight, and have reasonable cost.

Material development must strive to minimize systems weight. Army airframes historically become overloaded quickly during their service life, and tradeoffs in payload or ordnance must be made. Reduction in weight must however consider the risk level and cost effectiveness.

The terrain flight environment demands operating in an environment where wires and wire-like obstacles exist and terrain avoidance information is necessary during periods of reduced visibility, both day and night. A requirement exists for both wire cutters and wire detection. Tradeoffs in wire size to cut and detect will be required to optimize the system.

All development efforts must devote assets to systems integration. Where capabilities exist within the airframe system it should be incorporated and utilized and duplicated only when necessary. Use total systems integration approach.

During the development phase, countermeasures resistance must be designed in early. We are up against a sophisticated EW environment and must reduce susceptibility to jamming and spoofing.

Key to the display area is reduced aircrew workload. Provide the crew only the information they need when they need it or request it. With the small amount of real estate available in our cockpits, we can no longer afford the luxury of providing a dedicated instrument for every possible aircraft function. We must eliminate those instruments that are indicating normal operation 99.9% of the time. Remove all that type instrumentation and perform the monitor function through processors and provide that information to the aircrew only when it's <u>not</u> normal or is requested. Systems integration and displays designed to minimize cockpit real estate <u>should not</u> consolidate to a point that all functions - fire control, station keeping, communications, navigation, etc.- are incorporated into one display and increase crew workload. Systems engineer and optimize the number of displays required. Look at common displays that can pick up the workload of another when one fails.

Provide the highest reliability obtainable within reasonable cost and risk. We cannot afford to have the avionics systems to be the major source of low aircraft availability.

Design in ease of maintenance through built-in test, accessible test points, etc.

Listed here are a few of the key requirements documents which contain specifics:

ROC for night vision systems for Army aircraft.

Aircraft requirements documents for: AAH, AH-1, ASH (currently under study again), and OH58C.

Draft prepared LOA for day/night mast mounted sight system (MMSS).

Aviation night vision goggle system program.

Improved lighting system for Army aircraft (ILSAA) LOA.

I. INTRODUCTION

- TRADOC - ARMYS PRINCIPAL COMBAT DEVELOPER
- AVIATION CENTER PROPONENCY
- OTHER AREAS OF AVIATION INTEREST

II REQUIREMENTS GENERATION

- FIELD INPUT
- THREAT CAPABILITIES
- HQDA GUIDANCE/STUDIES
- KNOWN DEFICIENCIES
- REVIEW & UPDATE OF OLD REQUIREMENTS
- SCIENCE & TECH OBJECTIVES GUIDE (STOG)
- BATTLEFIELD DEVELOPMENT PLAN (BDP)

II REQUIREMENTS GENERATION (CONT.)

- MISSION AREA ANALYSIS (MAA)
- MISSION ELEMENT NEED STATEMENT (MENS)
- TECHNOLOGICAL BREAKTHROUGH
- SPECIAL REVIEWS & STUDIES
- PRODUCT IMPROVEMENT PROPOSALS (PIP)
- CONCEPT EVALUATION PROGRAMS (CEP)

III LIFE CYCLE MANAGEMENT

- LETTERS OF AGREEMENT (LOA)
- LETTER REQUIREMENTS (LR)
- REQUIRED OPERATIONAL CAPABILITIES (ROC)

IV COMBAT DEVELOPMENTS PROCESS (CDP)

DTD. AUG 78

- CONTAINS
  - EXPLANATION OF CDP
  - MASTER PLANNING SCHEDULES
  - INDIVIDUAL PROGRAM PLANNING SCHEDULE
  - MONTHLY PLANNING SCHEDULES
- PROVIDES TRADOC WITH PROPER TOOLS TO DIRECTLY INFLUENCE THE BUDGET AND IN EFFECT SHAPE THE FUTURE ARMY

V ARMY AVIATION IN THE HIGH THREAT ENVIRONMENT

- <u>GENERAL</u>
  - 24 HR CAPABILITY
  - NEAR EQUAL EFFECTIVENESS DAY & NIGHT
  - TERRAIN FLIGHT ENVIRONMENT
    - CONTOUR
    - LOW LEVEL
    - NAP OF THE EARTH
  - REDUCED VISIBILITY
    - NATURAL
    - MAN MADE
  - NAVIGATION/TARGET ACQUISITION

V ARMY AVIATION IN THE HIGH THREAT ENVIRONMENT (CONT.)

- MINIMIZE EXPOSURE TIME
- COMPLEMENT A/C SURVIVABILITY
- PASSIVE WHERE PRACTICAL
- MODULAR IN CONCEPT
- LIGHT WEIGHT
- OBSTICAL AVOIDANCE
  - TERRAIN
  - WIRE & WIRELIKE OBJECTS
- INTEGRATED INTO A TOTAL A/C SYSTEM
- COUNTERMEASURES RESISTANT
- MINIMIZE AIRCREW WORKLOAD
- HIGH RELIABILITY

V ARMY AVIATION IN THE HIGH THREAT ENVIRONMENT (CONT.)

- <u>SPECIFIC</u>
  - REQUIRED OPERATIONAL CAPABILITY (ROC) FOR NIGHT VISION SYSTEMS FOR ARMY A/C
  - A/C REQUIREMENTS DOCUMENTS
    - AAH
    - ASH (UNDER STUDY NOW)
    - AH-1
    - OH58C
  - DRAFT PROPOSED LETTER OF AGREEMENT FOR DAY/NIGHT MAST MOUNTED SIGHT SYSTEM (MMSS)
  - AVIATION NIGHT VISION GOGGLE PVS -- PROGRAM
  - IMPROVED LIGHTING SYSTEM FOR ARMY A/C (ILSAA)

TRI-SERVICE DISPLAY WORKSHOP
NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CA
16 JANUARY 1979

F-14 CONVERSION IN LIEU OF PROCUREMENT STUDY

MR. J. COLOMBO
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA 18974
215-441-3160

F-14 CILOP (CONVERSION IN LIEU OF PROCUREMENT) STUDY

The F-14 weapon system was developed to respond to a changing threat. Review of long range national policy has indicated a need for an updated carrier-based F-14 aircraft to protect the sea lanes of communication used by U.S. and friendly nations. Current national defense economics demand mission versatility and technology adaptation in current aircraft to meet this need rather than procuring totally new military systems. The objective of the F-14 CILOP is to increase the capability of the current aircraft to successfully perform the Maritime Air Superiority (MAS) mission against the threats of the 1990-2000 time period. The F-14 weapon system update to incorporate both present and future technology can be effective into the twenty-first century. A CILOP program is an economically and technologically realistic approach to accomplish this objective.

The Naval Air Development Center (NAVAIRDEVCEN) is designated primary field activity and technical coordinator for the F-14 CILOP program study during the Program Initiation Phase. The NAVAIRDEVCEN has been tasked to study and evaluate the baseline effectiveness and survivability of the F-14 aircraft against advanced alternative configurations in representative air-to-air environments and to perform the necessary system integration. Hughes Aircraft Company and Grumman Aerospace Corporation were primarily responsible for the generation of the alternative system configurations.

The purpose of this document is to briefly summarize the approach of the CILOP Program Initiation phase in terms of the successful accomplishment of the system integration and analysis objectives, and to indicate some selected Controls and Displays aspects of the study.

System integration objectives included:

1. Establish technical guidelines for contractor development of alternative configurations.

2. Evaluate contractor submitted technology/subsystems/system alternatives in the areas of performance, risk, cost and schedule.

Systems analysis objectives included:

1. Determine F-14 system baseline effectiveness and survivability for primary F-14 missions.

2. Determine system effectiveness and survivability of alternative F-14 CILOP configurations.

3. Compare effectiveness and survivability of alternate F-14 CILOP configurations to each other and to the baseline system.

4. Determine cost-effectiveness of the baseline system and CILOP alternatives.

This presentation focuses on the avionics systems requirements to meet MAS mission needs of the 1990's and beyond. Since the F-14 represents the exclusive Naval air capability for long range, standoff fleet air defense, it becomes imperative that the avionics be updated to continue to be responsive to the future threat.

Threats are categorized into two major categories: manned aircraft and cruise missiles, each of varying radar cross-section, altitude and speed categories.

Besides meeting the threat it becomes necessary to correct deficiencies in the avionics that reduce operational readiness-reliability and maintainability improvements, reduced logistics cost, and reduced dependence on ground support equipment.

Threat scenarios were postulated and approved.

A technology survey projecting mid-1980's state-of-the-art availability for avionics was conducted. Subsystem advances which represented up to moderate risk in schedule, cost and producibility were considered for CILOP alternatives.

Various system alternatives were subjected to system and cost effectiveness analysis based on approved methodologies and procedures. These alternatives were evaluated relative to each other and to the F-14 baseline configuration. The baseline was defined as an already improved version of the current system so as not to exaggerate the improvements due to the CILOP. The most cost effective alternative was recommended for assessment during the follow-on Demonstration and Validation phase of the program.

A major avionic subsystem is the Controls and Displays. The operational needs which help define the Controls and Displays requirements include operational and system needs. Operationa needs include:

- Multiple targets
- Complex raid structures
- Identification requirements
- ACM quick reaction
- Mission completion
- ECM environment
- Fleet interoperability

System needs include:

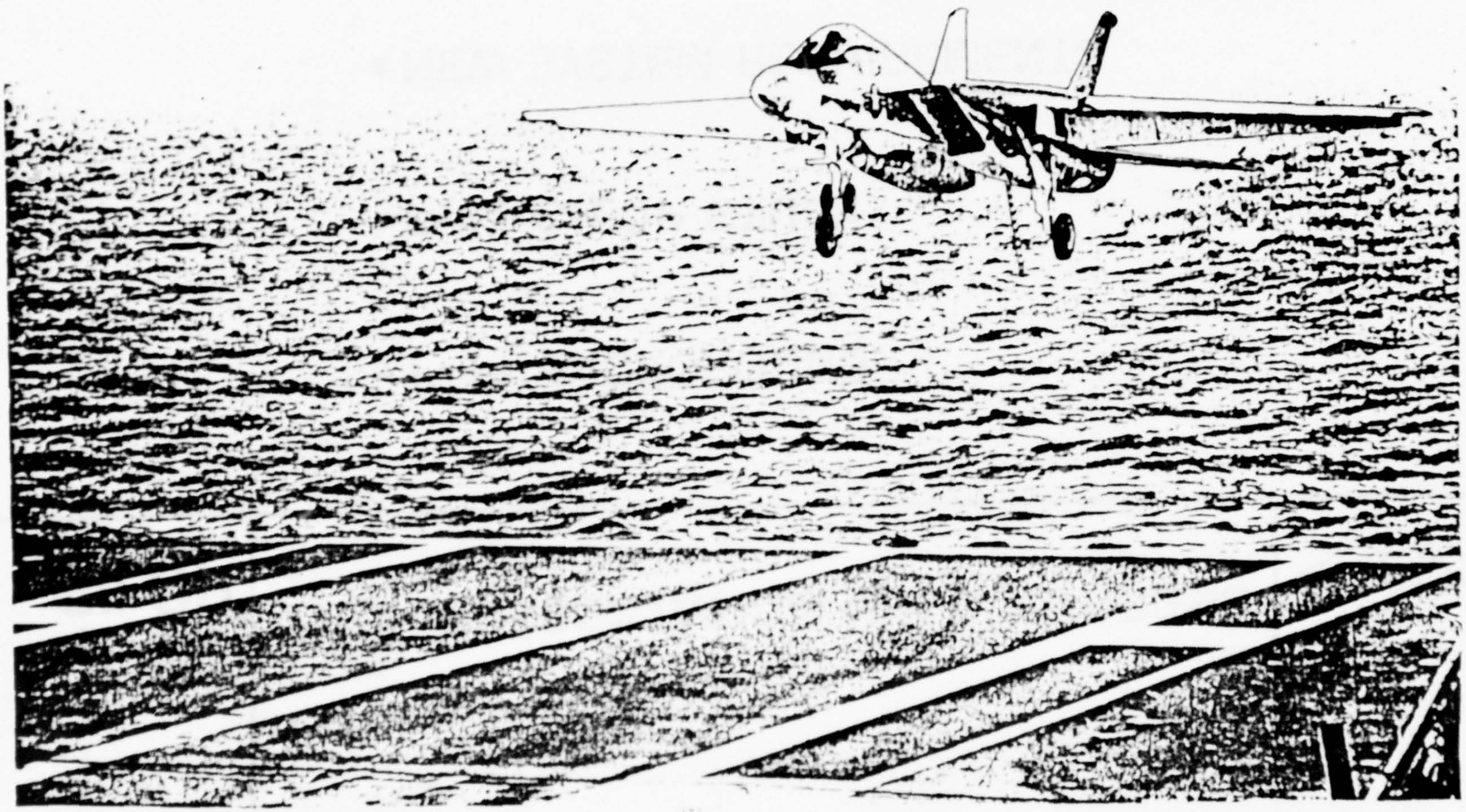
- Data availability
- Processing capability
- Redundancy
- Flexibility
- Data formatting
- Operator workload
- Weapon requirements

Display recommendation for CILOP consisted of an integrated Controls and Displays subsystem, based on the Airborne Integrated Display System concept, to include:

- Redundant programmable digital processors
- Multifunction displays
- Dawn to Dusk Television Identification System
- Dual Cockpit Helmet Mounted Sight

MR J. COLOMBO,
NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PA

F-14 CILOP STUDY



F-14 CILOP | THIS PRESENTATION WILL ADDRESS | NADC

- F-14 BACKGROUND
- F-14 CILOP STUDY
- NEW SYSTEM REQUIREMENTS

F-14
CILOP

THIS PRESENTATION WILL ADDRESS

NADC

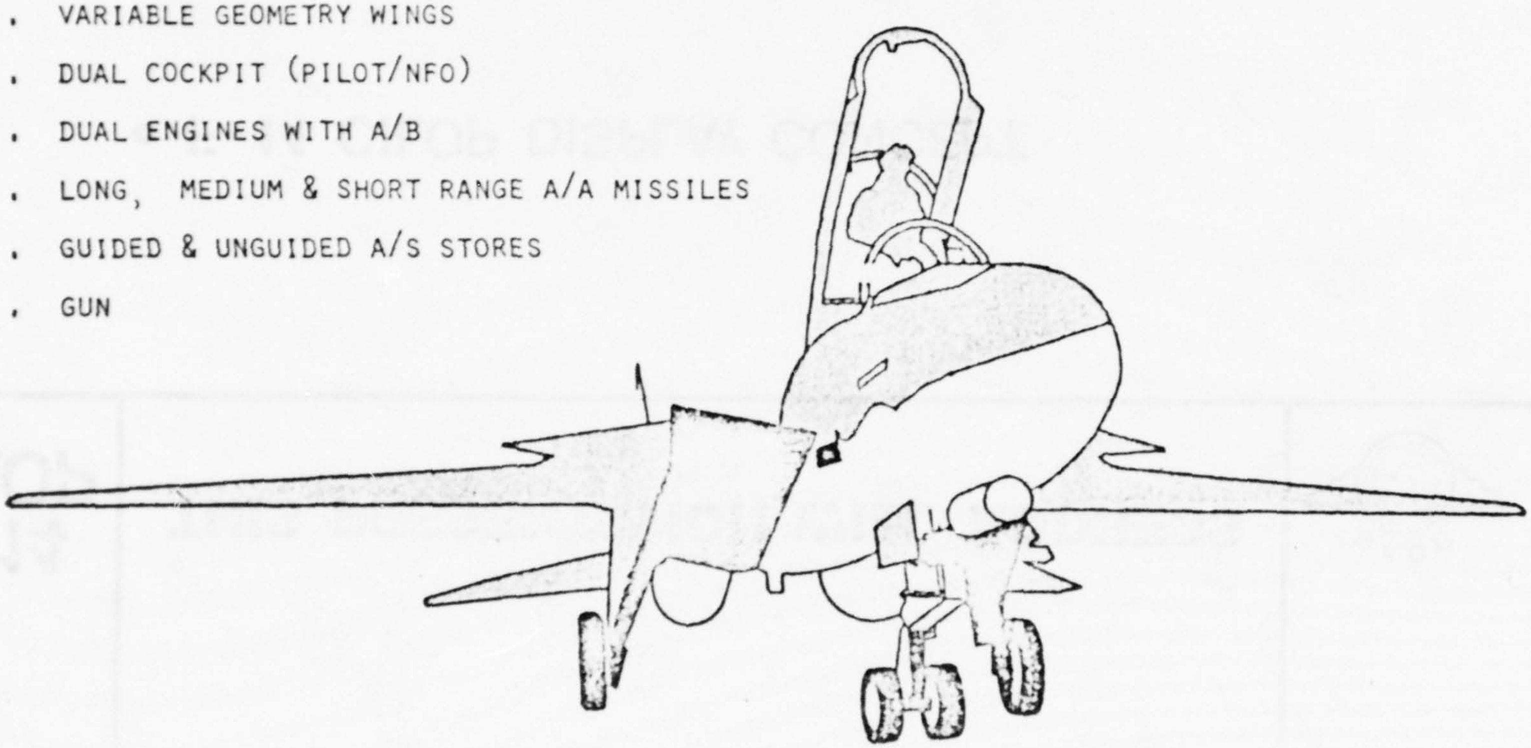
- F-14 CILOP DISPLAY CONCEPT
- INTEGRATED DISPLAYS AND CONTROLS
- F-14 CILOP EO SENSOR CONCEPT

F-14
CILOP

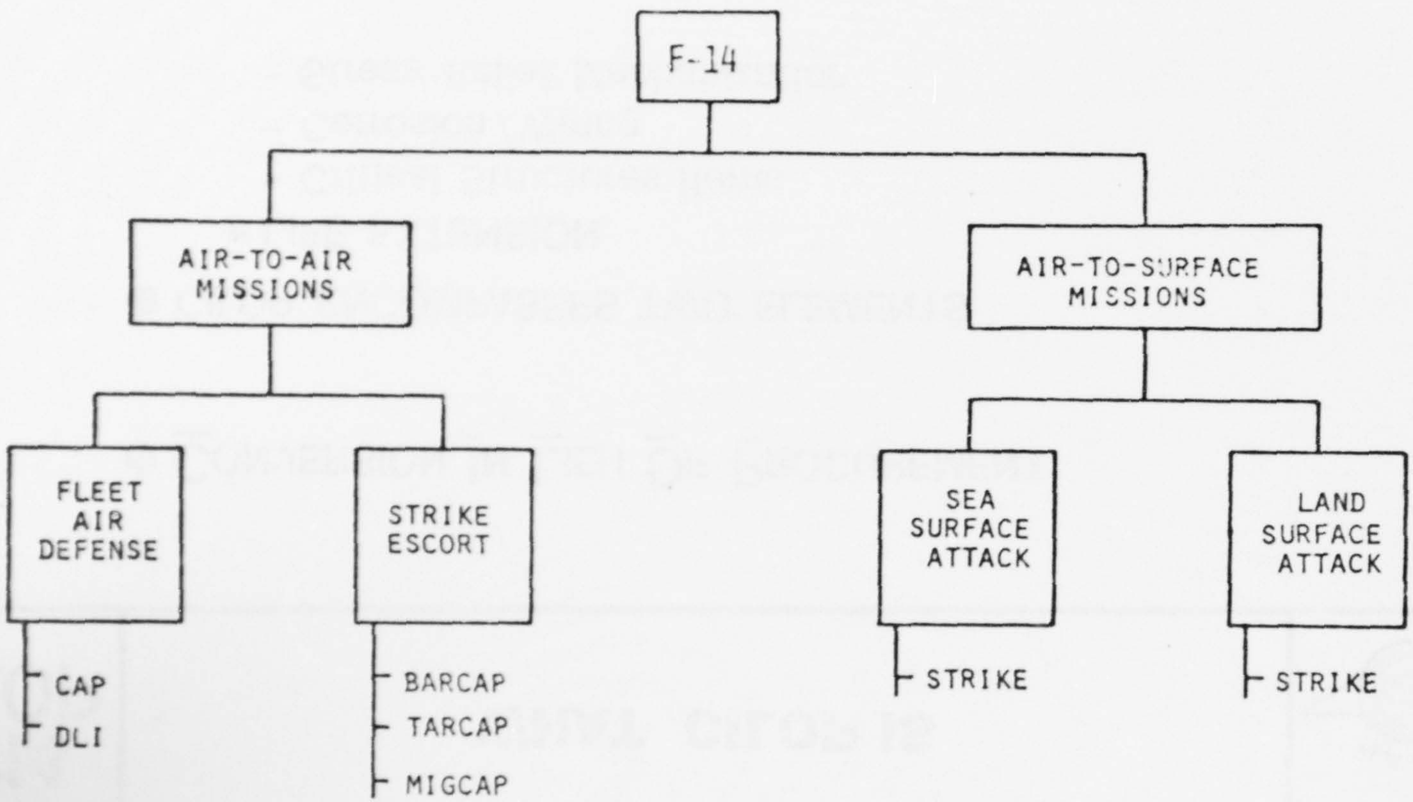
THE F-14A

NADC

- AIR SUPERIORITY FIGHTER
- ALL WEATHER
- DAY/NIGHT
- VARIABLE GEOMETRY WINGS
- DUAL COCKPIT (PILOT/NFO)
- DUAL ENGINES WITH A/B
- LONG, MEDIUM & SHORT RANGE A/A MISSILES
- GUIDED & UNGUIDED A/S STORES
- GUN



F-14 MISSION DEFINITION



F-14 CILOP

WHAT CILOP IS

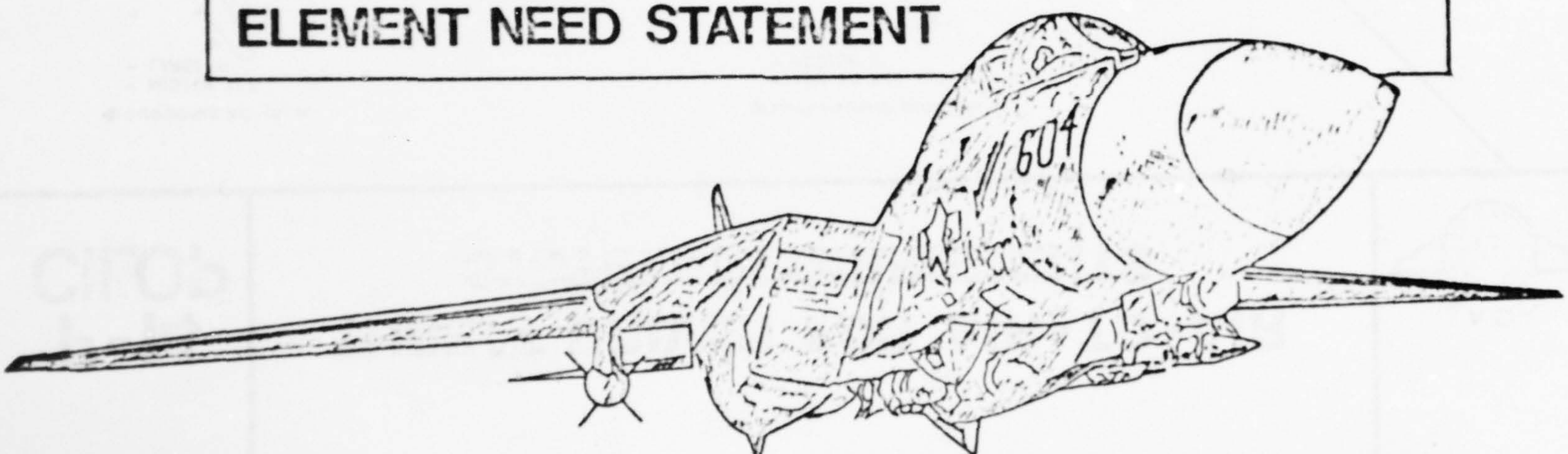
- CONVERSION IN LIEU OF PROCUREMENT

- CILOP ENCOMPASSES TWO ELEMENTS
  - LIFE EXTENSION
    - Critical Structures Items
    - Corrosion / Wiring
    - Stress Relief Mechanization
  - CAPABILITY UPGRADE
    - Increase Effectiveness Against Projected Threat
    - Increase Operational Readiness

F-14 CILOP

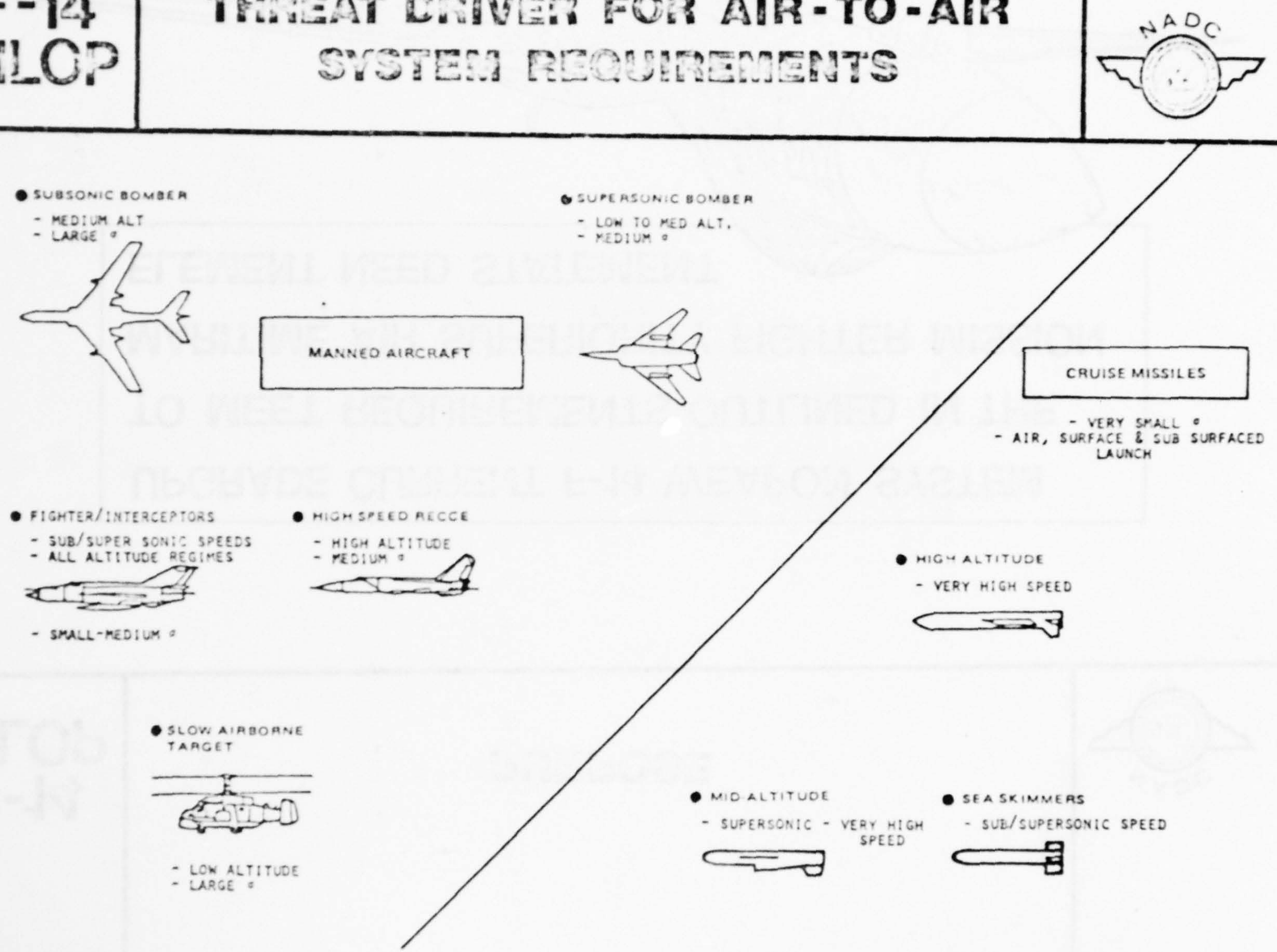
PURPOSE

UPGRADE CURRENT F-14 WEAPON SYSTEM TO MEET REQUIREMENTS OUTLINED IN THE MARITIME AIR SUPERIORITY FIGHTER MISSION ELEMENT NEED STATEMENT



F-14 CILOP

THREAT DRIVER FOR AIR-TO-AIR SYSTEM REQUIREMENTS



THREAT SCENARIOS

▶ PRIORITY LISTING

• Fighter Mission Subset

1) SCENARIO #1 - HIGH INTENSITY, 1985 TO 1990 TIME PERIOD
   . MAS MISSION SUBSET ELEMENT
2) SCENARIO #5 - HIGH INTENSITY, 1990 TO 2000 TIME PERIOD
   . MAS MISSION SUBSET ELEMENT
3) SCENARIO #2 - MEDIUM INTENSITY, 1985 TO 1990 TIME PERIOD
   . MAS MISSION SUBSET ELEMENT
4) SCENARIO #4 - HIGH INTENSITY, 1985 TO 1990 TIME PERIOD
   . AMPHIBIOUS OPERATIONS MISSION SUBSET ELEMENT
   . OVERLAND PENETRATION MISSION SUBSET ELEMENT
5) SCENARIO #6 - MEDIUM INTENSITY, 1990 TO 2000 TIME PERIOD
   . MAS MISSION SUBSET ELEMENT
6) SCENARIO #3 - LOW INTENSITY, 1985 TO 1990 TIME PERIOD
   . MAS MISSION SUBSET ELEMENT

F-14
CILOP

OPERATIONAL READINESS DRIVES SYSTEM REQUIREMENTS

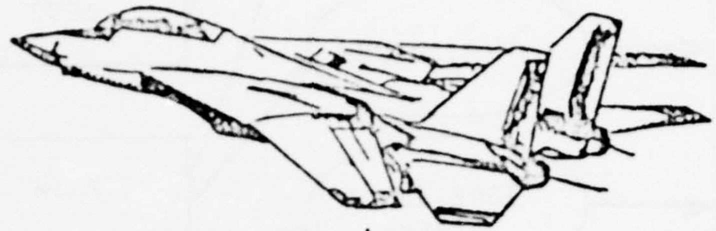
NADC

- IMPROVED AVAILABILITY
- REDUCED LOGISTICS AND MAINTENANCE COST
- REDUCE DEPENDENCE ON PGSE

F-14 CILOP

TECHNOLOGY / SUBSYSTEM SURVEY

NADC



VEHICLE

. ELECTRICAL
. AIRFRAME
. FLIGHT CONTROLS
. ENVIRONMENTAL CONTROLS

AVIONICS

. COMMUNICATIONS
. NAVIGATION
. CONTROLS & DISPLAYS
. COMPUTERS
. RADAR
. ELECTRO-OPTICAL SENSORS
. ELECTRONIC WARFARE
. PROCESSING

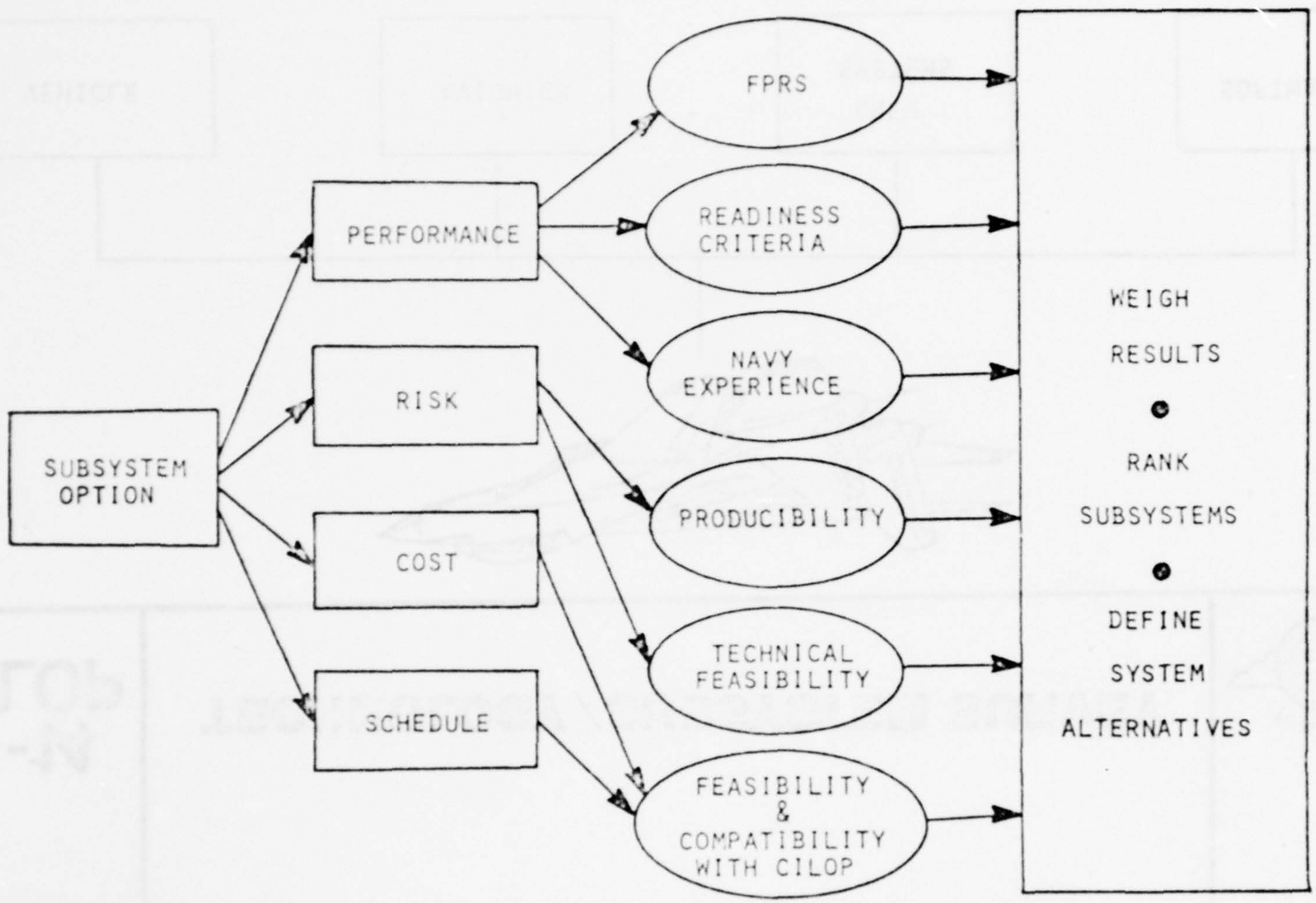
CREW SYSTEMS

. LIFE SUPPORT
. ESCAPE SYSTEMS
. TRAINING

SOFTWARE

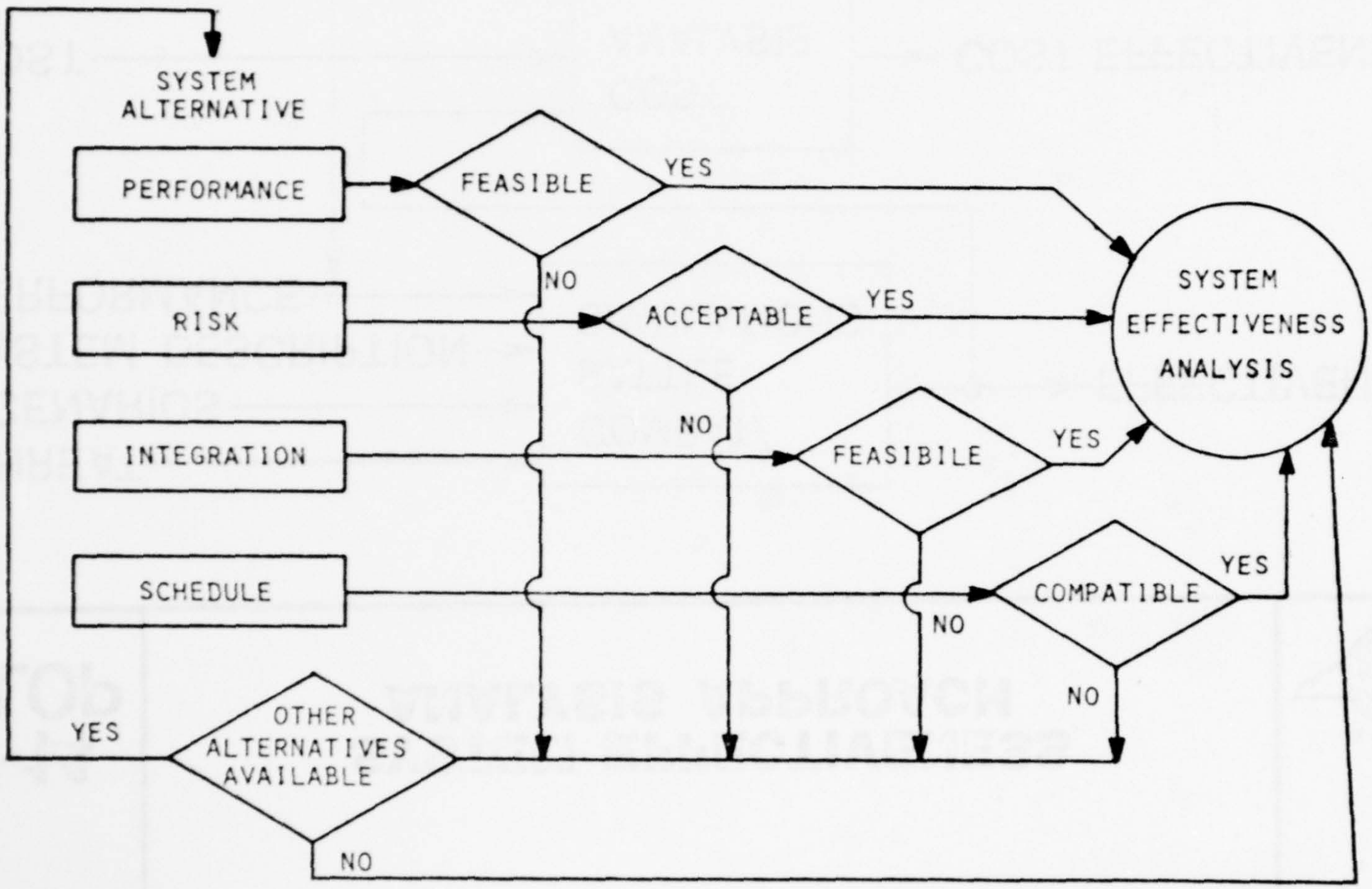
F-14 CILOP

SUBSYSTEM EVALUATION METHODOLOGY



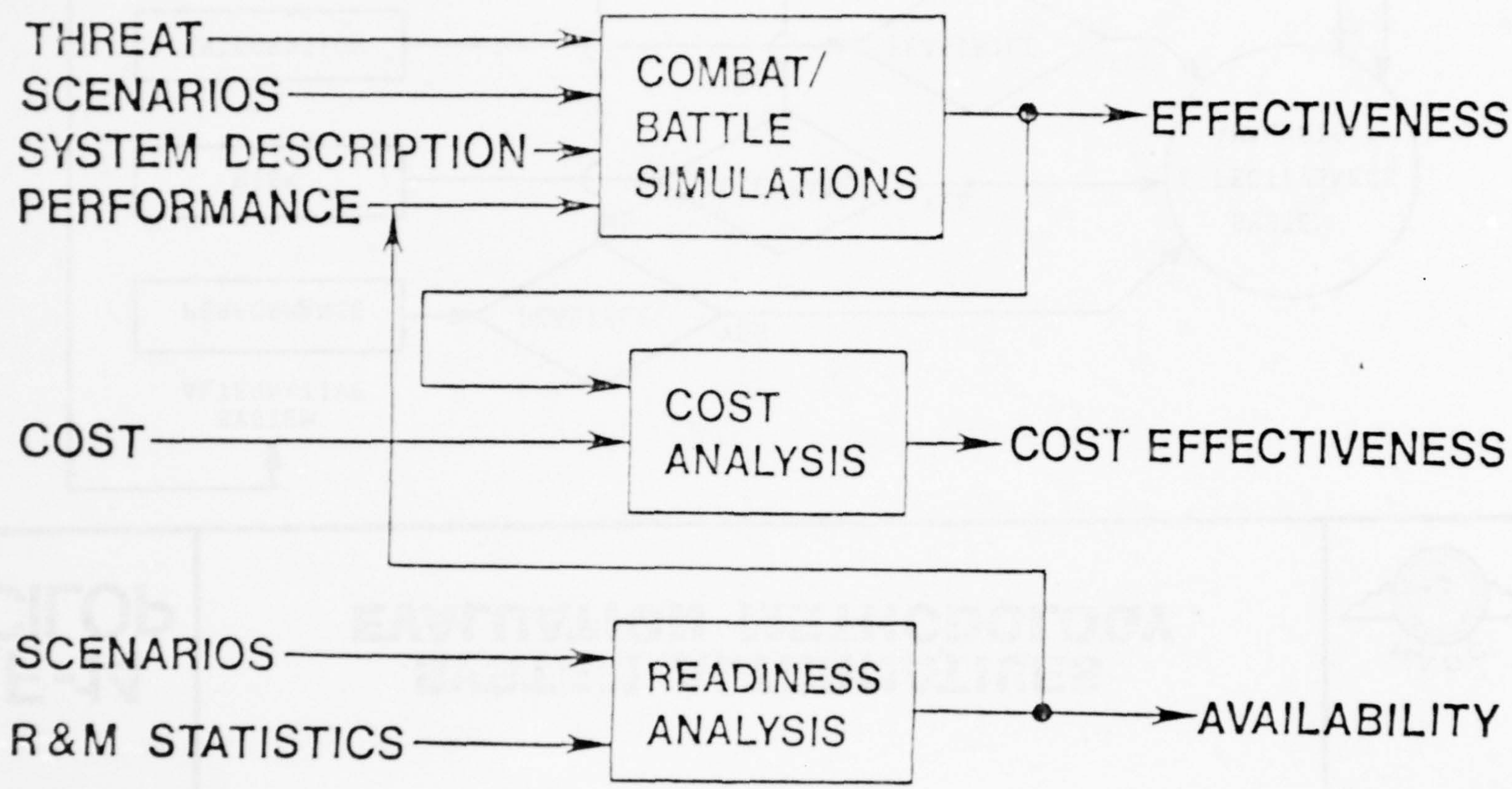
F-14
CILOP

SYSTEM ALTERNATIVES EVALUATION METHODOLOGY

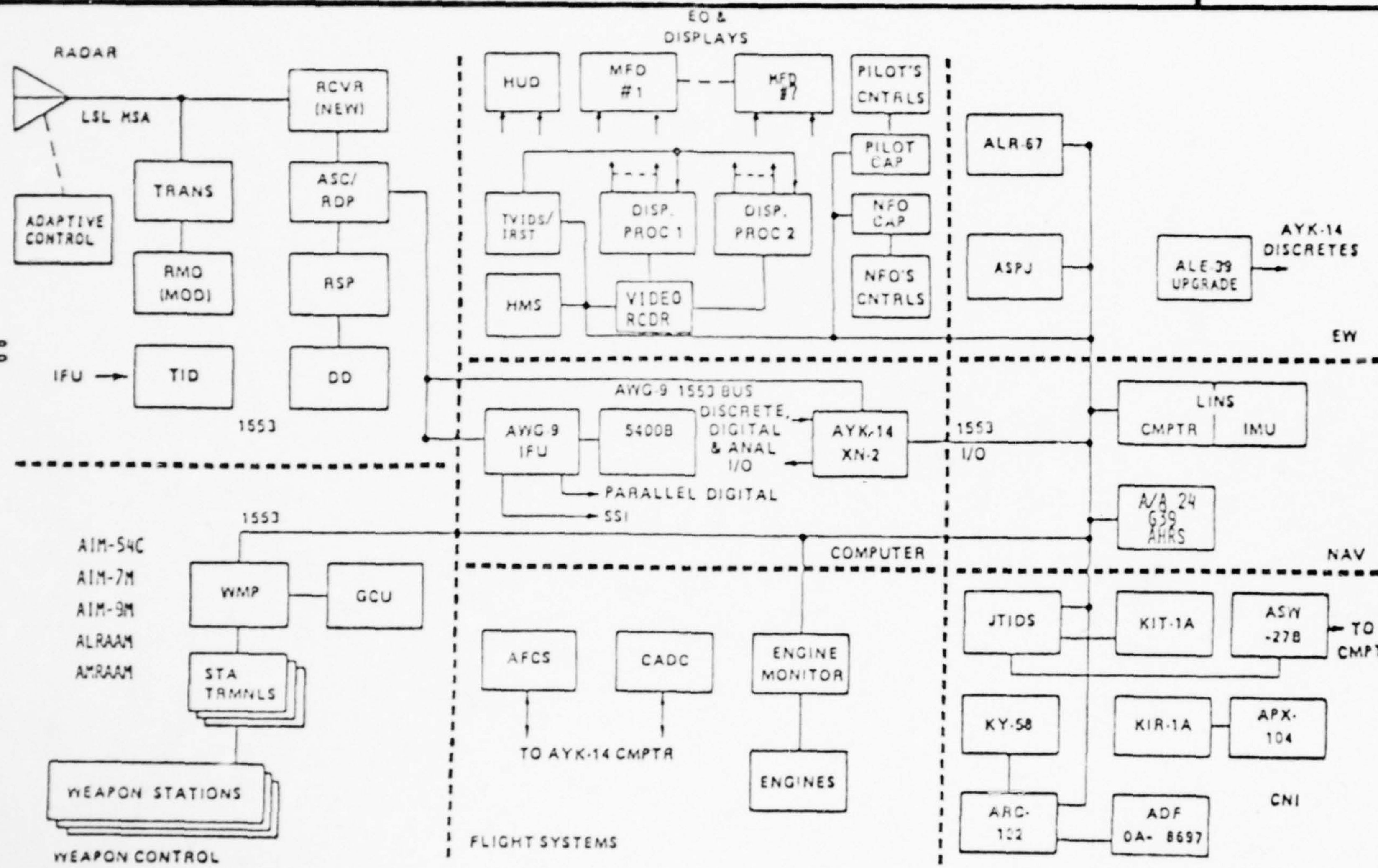


F-14 CILOP

SYSTEM EFFECTIVENESS ANALYSIS APPROACH



F-14 CILOP CONFIGURATION



SESSION II - SYSTEM REQUIREMENTS

F-16 EXPANDED CAPABILITY INITIATIVES

MAJOR J. JERRY ARMSTRONG

ASD/YPRS AUTOVON 785-5812/6833

The evolution of aircraft changes can potentially be a painful process for personnel assigned to an aircraft program office. The definition of requirements, program direction, the budget cycle, the definition of aircraft changes, and the contract change procedures is frequently a lengthy process at best. Developments which are not under control of the program office and which are not time-phased with program activities can further complicate the life of project managers, engineers, and others in the program office. One key to success is anticipation of requirements by the program office. We must take the initiative in planning for potential changes.

While formal methods exist for operating commands to state requirements and for higher headquarters to issue direction so that the program office can proceed with changes, there must be a significant level of "hand holding" to assure the orderly evolution of a change. The program office has a responsibility to take the initiative to work with the operating commands and higher headquarters to assure that all options are considered in light of current and future technology, schedule, budget limitations, etc. The program office and the laboratories must similarly work together to assure that potential requirements, program considerations, and development efforts are coordinated. And of course, that is what the Tri-Service Workshop and this briefing is all about.

A team of officers from the F-16 System Program Office recently completed a study to define expanded capability options for the F-16. The objectives of the team were to identify candidate technologies and development programs that have potential F-16 application, to identify development voids, to assess options for F-16 missions, and to recommend initiatives to expand the capability of the F-16. The team worked closely with the various Air Force laboratories in evaluating technology and development programs.

The team also worked hand-in-hand with personnel representing Tactical Air Command in assessing the projected threat, current and expanded F-16 missions, current and future technology, current development programs and other collateral factors. That assessment led to configuration options that were then viewed in relation to development considerations (aircraft compatibility, performance, etc) and budget realities. Operational considerations such as force structure requirements, user needs, and the utility of the expanded capability options were not considered since this is the responsibility of the operational community.

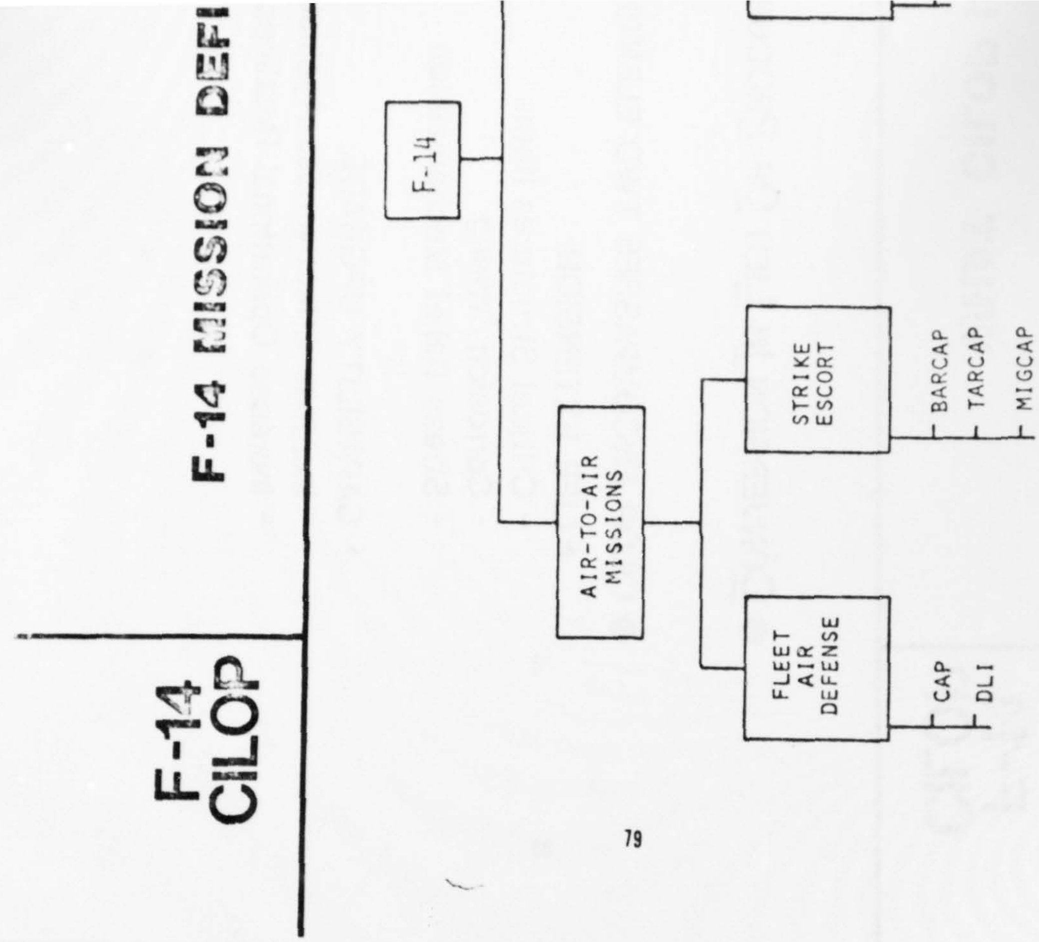
The discrete technical options were assessed from a technical viewpoint in terms of their potential contribution to the F-16 current and potential air-to-air missions (within visual range and beyond visual range) and current and potential air-to-ground missions (day, night, adverse weather). In looking at potential integration impacts of such systems or subsystems as the Joint Tactical Information Distribution System (JTIDS), advanced sensors such as FLIR and TV tracking/laser designator pods, E-O weapons, etc., it quickly became evident that display options would play an integral part, indeed a vital role, in the expanded capability definition. Multiple sensors and the requirement to display situation awareness data to the pilot would have a significant impact on the number of displays, their position in the cockpit, and the integration of those displays into the total F-16 avionics architecture.

In evaluating the schedules for on-going development programs, it was obvious that display development will have to proceed in an orderly fashion to meet the milestones of those programs. Furthermore, the schedules of concurrent decision milestones, further complicate the task of defining aircraft integration impacts including new display requirements.

Recommendations of the team included putting a planning wedge in the FY 81 R&D budget submission. Hopefully, display technology will continue to mature to assure a timely transition of the matured technology to engineering development in the FY 81 timeframe. If the technology progresses adequately and is consistent with F-16 requirements, leadtimes will be protected.

Two display options are particularly critical in terms of technology and long lead development. The first is a wide field of view HUD for display of FLIR video. The second is a Tactical Situation Display (TSD) for situation awareness including display of JTIDS data. The TSD is a moving map display with an overlay capability. Another option, although not so critical in terms of technology, is a multipurpose CRT display.

In conclusion, the potential exists to substantially improve and expand F-16 mission capabilities. But in order to significantly impact the future F-16 production deliveries, in terms of minimizing retrofit, development must start now in some critical areas. Current aircraft displays will be over committed and inadequate for expanded capability options. Hopefully, past, current, and future development efforts will have matured technology to the point such that when improved and/or expanded capability options are directed, the displays will not be the pacing item in terms of leadtime. For the F-16 those display developments will present particular challenges. In particular, the available cockpit space and high ambient light levels will present challenges. Also, human factor considerations associated with not over-tasking a single-seat fighter pilot will be a critical factor. Changing



missions, sensors, avionics, etc., will require the flexibility associated with software programmable displays.

The bottom line - the research and development community and the system acquisition community must work hand-in-hand to anticipate requirements while always considering the "real world" limitations of technology and aircraft integration. This is essential to both development and acquisition programs.

AD-A077 061 AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH F/G 17/5
DISPLAY WORKING GROUP JOINT DARCOM/NMC/AFLC/AFSC PANEL ON THE F--ETC(U)
OCT 79 W N KAMA , W L MARTIN , G G KUPERMAN
UNCLASSIFIED AMRL-TR-79-101 NL

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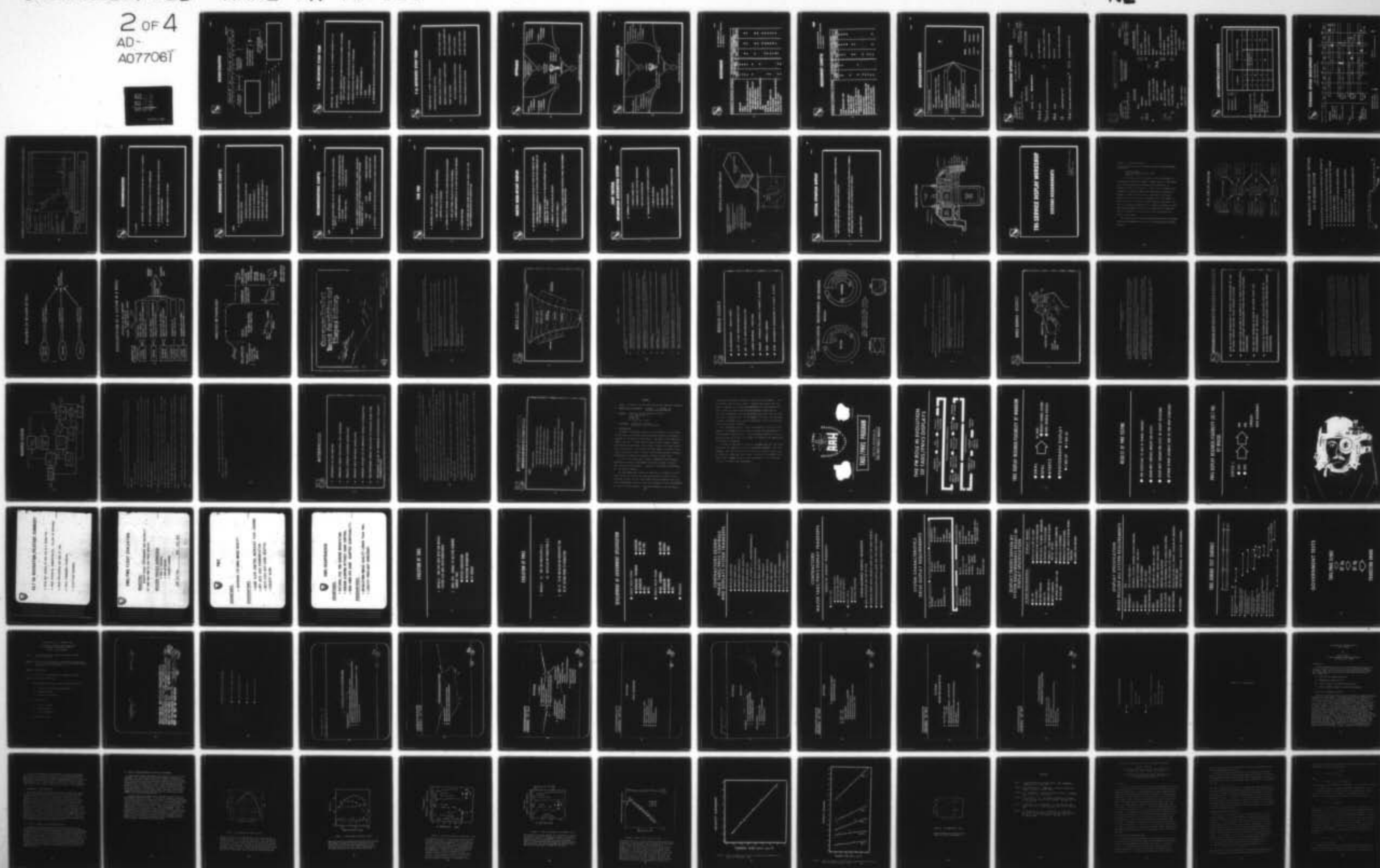

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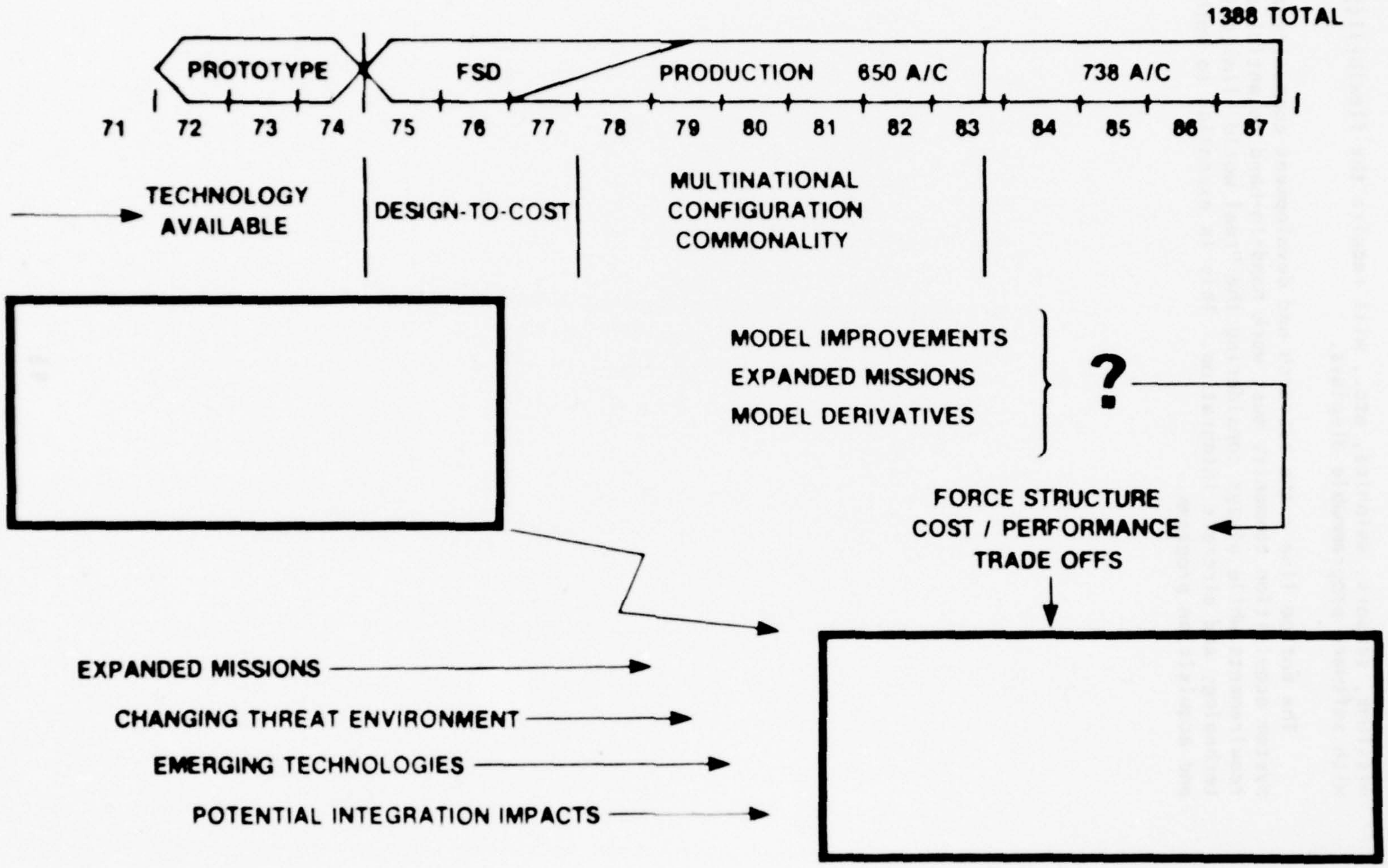
DESIGN EVOLUTION



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F-16 INITIATIVES STUDY TEAM

DIRECTION: HQ AFSC/SD MSG 11 JUL 78 "EXPANDED CAPABILITY F-16"

OBJECTIVES:

- IDENTIFY CANDIDATE TECHNOLOGIES/DEVELOPMENT PROGRAMS FOR F-16 APPLICATION
- IDENTIFY VOIDS IN F-16 RELATED DEVELOPMENT OPTIONS
- ASSESS POTENTIAL OPTIONS FOR F-16 MISSIONS
  - A/C COMPATIBILITY
  - PERFORMANCE/CAPABILITY
  - COST
  - SCHEDULE
- RECOMMEND INITIATIVES TO ACHIEVE EXPANDED CAPABILITY F-16

26K8

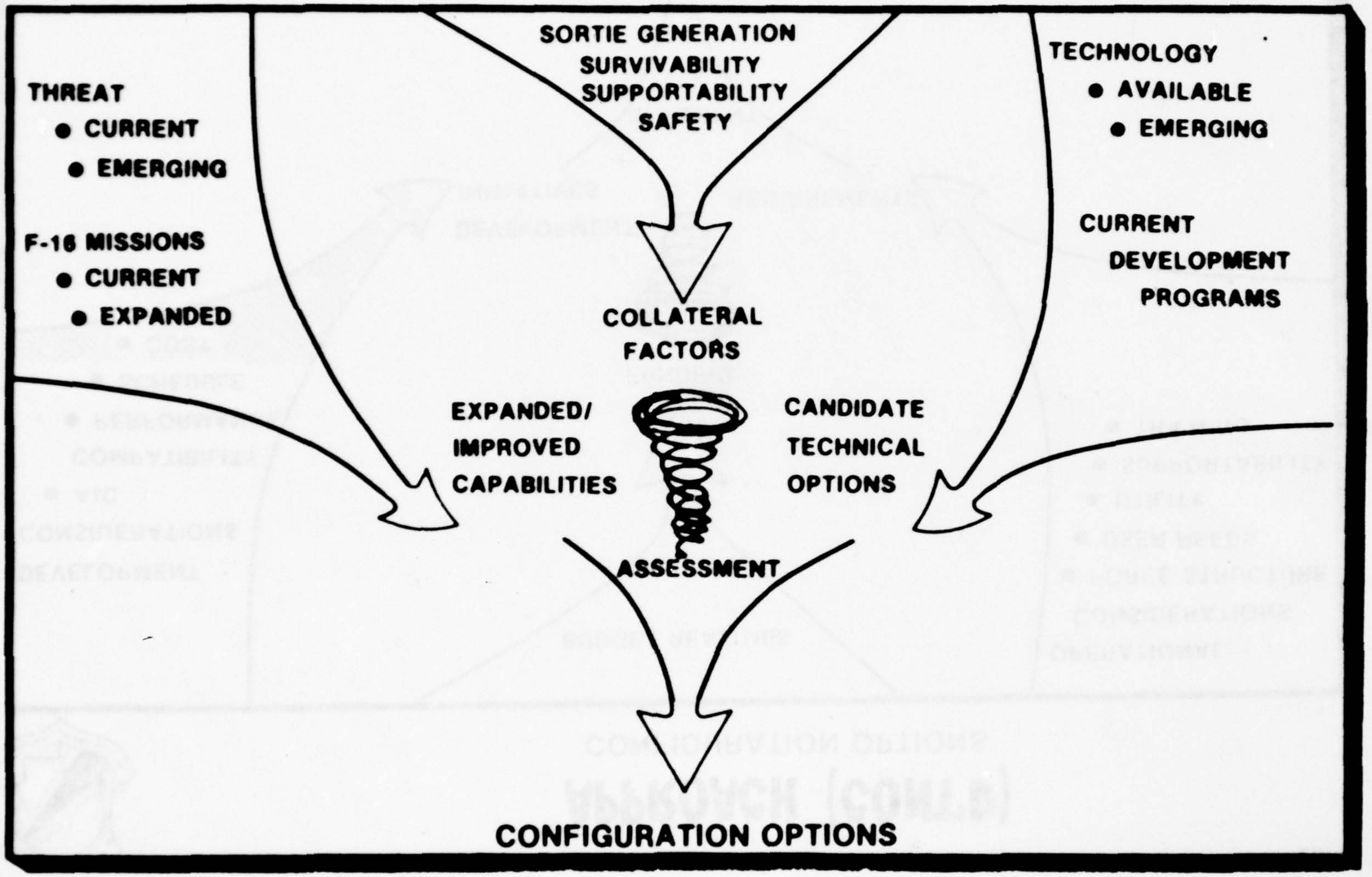
F-16 INITIATIVES STUDY TEAM

COMPOSITION: F-16 SPO---TAC/REQUIREMENTS

PARTICIPATION/CONSULTATION:

AERONAUTICAL SYSTEMS DIVISION	AIR NATIONAL GUARD
WRIGHT AERONAUTICAL LABORATORIES	EPG/OPS SUBCOMMITTEE
JOINT TEST FORCE	GENERAL DYNAMICS
PILOTS/MAINTENANCE PERSONNEL	PRATT & WHITNEY
TACTICAL FIGHTER WEAPONS CENTER	OTHER CONTRACTORS
FOREIGN TECHNOLOGY DIVISION	OTHER USAF AGENCIES

APPROACH



THREAT
● CURRENT
● EMERGING
F-16 MISSIONS
● CURRENT
● EXPANDED
SORTIE GENERATION
SURVIVABILITY
SUPPORTABILITY
SAFETY
TECHNOLOGY
● AVAILABLE
● EMERGING
CURRENT
DEVELOPMENT
PROGRAMS
COLLATERAL
FACTORS
EXPANDED/
IMPROVED
CAPABILITIES
CANDIDATE
TECHNICAL
OPTIONS
ASSESSMENT
CONFIGURATION OPTIONS

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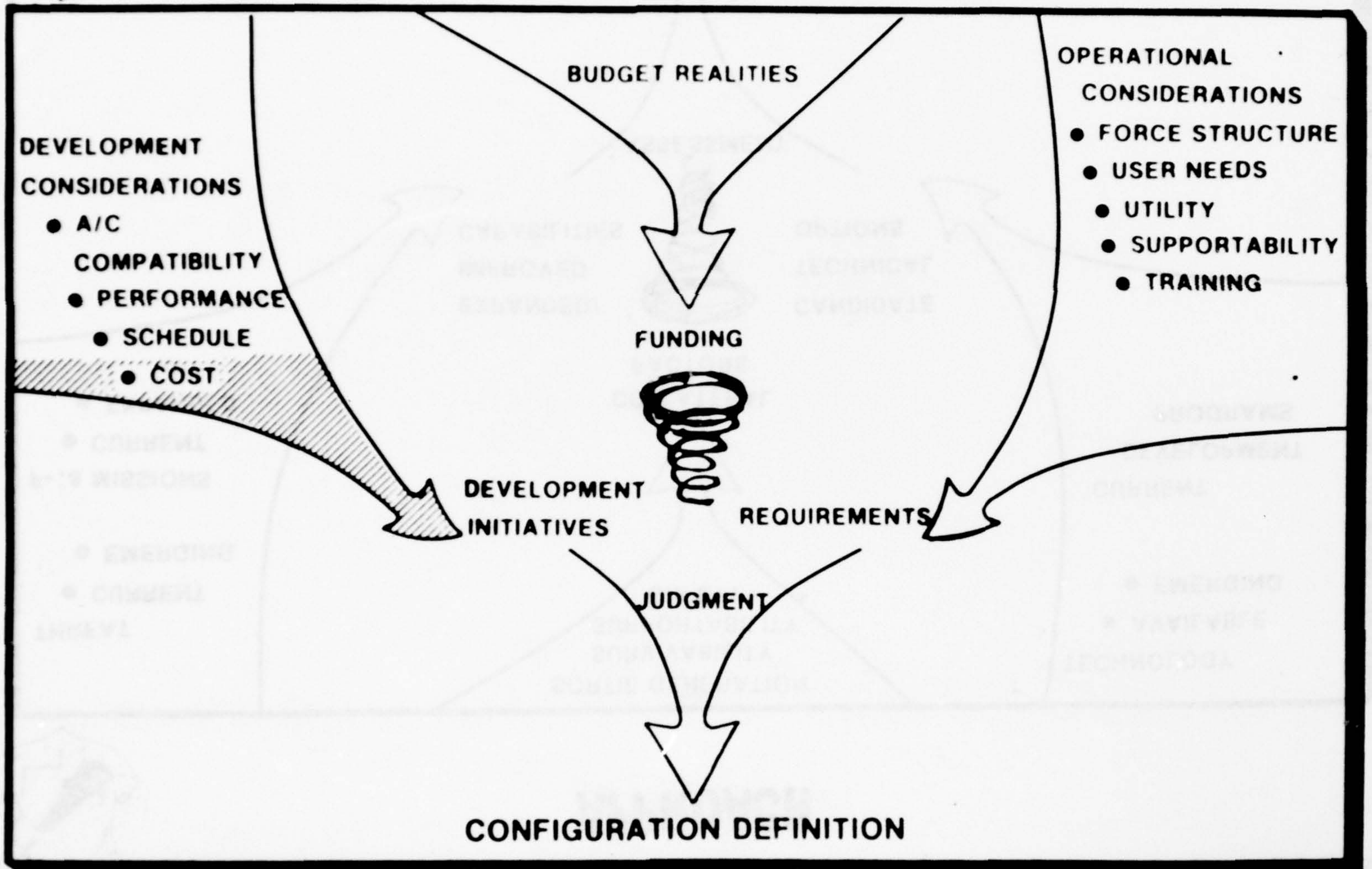
APPROACH (CONT'D)

CONFIGURATION OPTIONS



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ASSESSMENT

● - EXPANDED/NEW
+ - SIGNIFICANTLY IMPROVED
✔ = IMPROVED

CANDIDATE TECHNICAL OPTIONS	EXPANDED/IMPROVED CAPABILITIES				
	AIR-TO-AIR		AIR-TO-SURFACE		
	WVR	BVR	DAY	NIGHT	ADV WX
AMRAAM	+	●			
AIM-7	✔	●			
JTIDS	+	●	●	●	●
TACTICAL SITUATION DISPLAY	+	+	+	+	+
RADAR IMPROVEMENTS					
TWS/RAID ASSESS/JEM-IFF	+	●			
IMP DBS/GMTI/GMTT			+	●	●
TERRAIN AVOIDANCE				●	●
INC RADAR DETECTION RANGE		+			
SAR				+	+
WAAM			+	●	●
FLIR (POD)	+		+	●	✔
WIDE FOV/VIDEO HUD	+		✔	●	✔
IIR MAVERICK			+	●	+
ADV LASER DESIGNATOR (POD)			●	✔	✔
TVSU/TISEO (POD)	+	●	+		
ACTIVE IFF/EIFF	+	●			

[redacted]

ASSESSMENT (CONT'D)

● - EXPANDED/NEW
✚ - SIGNIFICANTLY IMPROVED
✔ - IMPROVED

CANDIDATE TECHNICAL OPTIONS	EXPANDED/IMPROVED CAPABILITIES				
	AIR-TO-AIR		AIR-TO-SURFACE		
	WVR	BVR	DAY	NIGHT	ADV WX
IECM	+	+	+	+	+
JAM RESISTANT UHF	+	+	+	+	+
GPS			+	+	+
RADAR ALTIMETER				+	+
IMP 20MM ROUND	+				
30MM GUN (POD)			+	✔	
GBU-15 (DATA LINK GP A)			+	✔	
ENGINE PERFORMANCE IMPROVEMENTS	+	✔			
DIRECTOR SIGHT	+		✔		
INCREASED AMMUNITION CAP	✔				
INTEGRATED FIRE/FLT CONT	✔		✔		
HELMET MOUNTED SIGHT	✔		✔		
MANEUVER ENHANCEMENT	✔		✔	✔	✔

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INTEGRATION CONCERNS

EMERGING TECHNOLOGIES

- FLIR
- PROGRAMMABLE SIGNAL PROCESSING
- CCV / INTEGRATED FIRE / FLIGHT CONTROL
- DISPLAYS

EXPANDED MISSIONS

- AUTONOMOUS PRECISION STRIKE
- AUSTERE NIGHT
- AIR SUPERIORITY GROWTH
- COLLATERAL MISSIONS

POTENTIAL INTEGRATION IMPACTS

- JTIDS
- GPS
- AMRAAM
- ADV DAY LASER DESIGNATOR
- IECM

?

SPACE	PERFORMANCE
POWER	DISPLAYS
COOLING	AVIONICS
COST	SCHEDULE

35K8

CONFIGURATION OPTIONS (CONT'D)

REQUIREMENTS
VOLUME (FT^3) □
COOLING (KW) △
DISPLAYS ○ EXISTING (N) NEW

A/C COMPATIBILITY CONSIDERATIONS

RESERVES

	A	B
VOLUME (FT^3)	6	-
COOLING (KW)	1.3	.8

MULTIMISSION

ENGINE "ILITY" **IMPROVEMENTS**

1.6 △2 (N) JTIDS

.5 △ (N) TACTICAL SITUATION DISPLAY

3.6 △1.3 IECM

.5 JAM RESISTANT UHF

.2 △3 ○ RADAR IMPROVEMENT PACKAGE*

COLLATERAL FACTORS

SATS

A/C GND MOBILITY

□ ADDITIONAL CHAFF/FLARES

REDUCED IR SIGNATURE

NEW EPU

AUTO INS/SMS DATA LOADING

3 △1 ENGINE DIAGNOSTICS

34K8

CONFIGURATION OPTIONS

REQUIREMENTS

VOLUME (FT³) □
COOLING (KW) △
DISPLAYS ○ EXISTING Ⓝ NEW

A/C COMPATIBILITY CONSIDERATIONS

RESERVES

	A	B
VOLUME (FT³)	6	-
COOLING (KW)	1.3	.8

AIR-TO-AIR

BVR:

□ AMRAAM

□ .8 △ .8 AIM-7

RADAR IMPROVEMENTS

TRACK WHILE SCAN

RAID ASSESSMENT

JEM-IFF

□ △ INC DETECTION RANGE

□ ACTIVE IFF/EIFF

○ TVSU/TISEO (POD)

WVR:

IMP 20MM ROUND

DIRECTOR SIGHT

AIR-TO-SURFACE

Ⓝ RADAR TERRAIN AVOIDANCE

○ FLIR (POD)

Ⓝ WIDE FOV/VIDEO HUD

□ .2 RADAR ALTIMETER

WAAM

□ .9 △ .2 GPS

○ ADV LASER DESIGNATOR

○ IIR MAVERICK

30MM GUN (POD)

○ GBU-15 (DATA LINK GP A)

RADAR IMPROVEMENTS

GMTI/GMTT

IMP DBS

A/C COMPATIBILITY CONSIDERATIONS

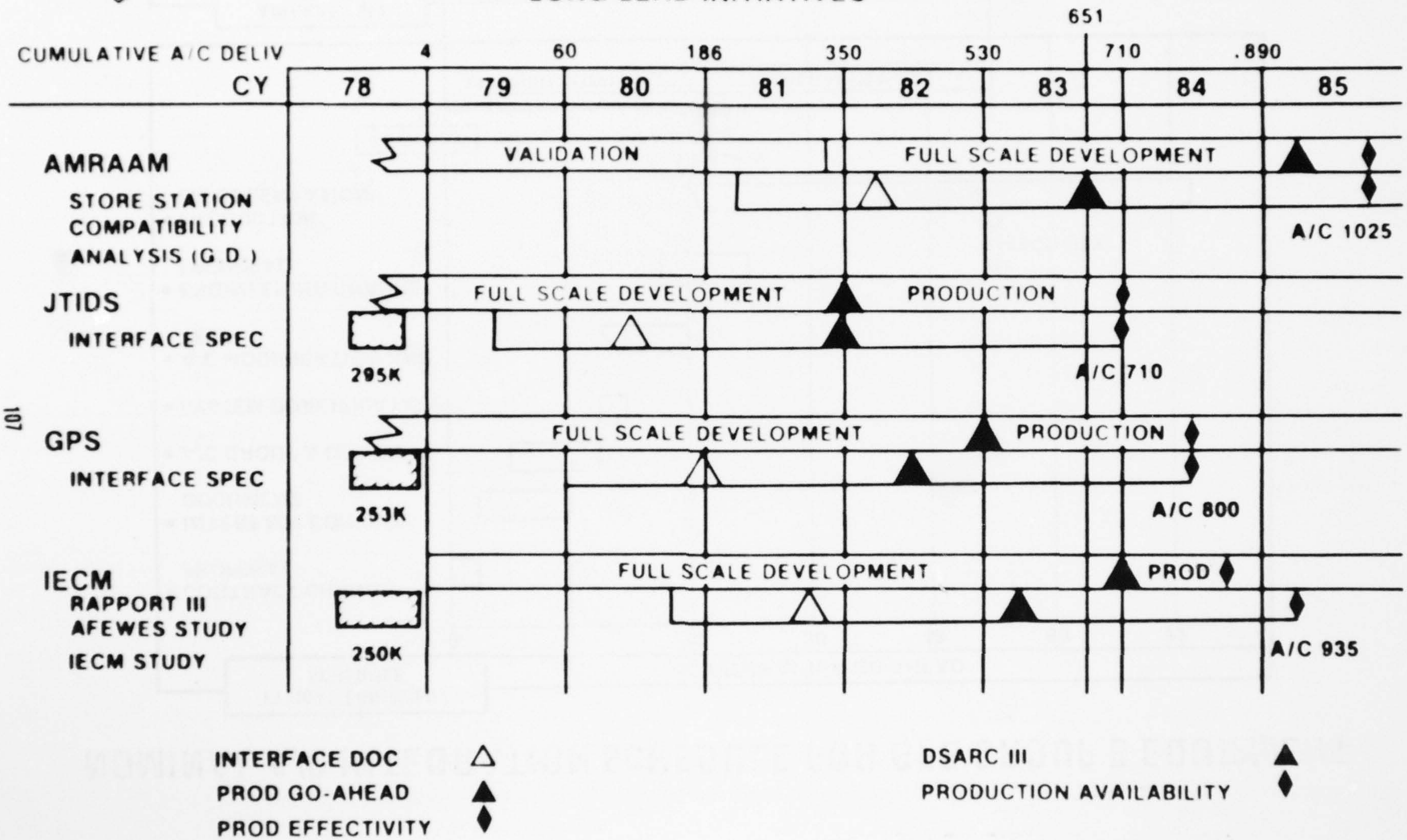
ADEQUATE ✓
MARGINAL M
INADEQUATE ×

	CONFIGURATION			
	CURRENT		TECHNICAL OPTIONS	
	A	B	A	B
● AVIONICS VOLUME	✓	✓	M (ECM POD) × (IECM)	×
● AVIONICS COOLING (6.5 KW)	✓	M	×	×
● DISPLAYS (RDR-EO/SMS/HUD)	✓	✓	×	M
● MAX TOGW (35,400 lb.)	✓	✓	M	M

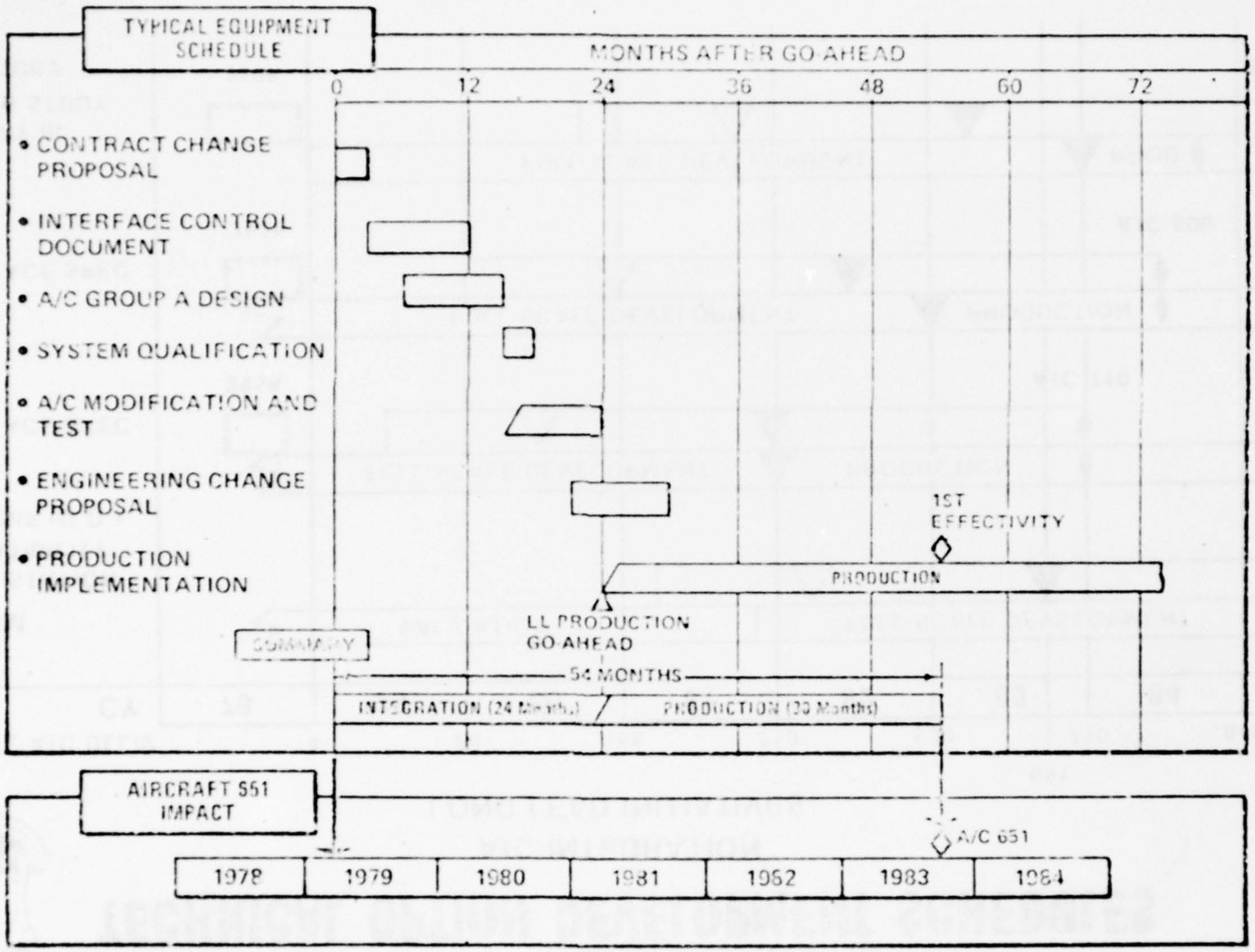
TECHNICAL OPTION DEVELOPMENT SCHEDULES

62K8

A/C INTEGRATION
LONG LEAD INITIATIVES



NOMINAL A/C INTEGRATION SCHEDULE FOR GFE GROUP B EQUIPMENT



56K8

RECOMMENDATIONS

F-16 SPO

- CONTINUE LONG LEAD INITIATIVES WITHIN FY 79/80 F-16 BUDGET
- PUT PLANNING WEDGE IN FY 81 POM SUBMISSION
- PROCEED WITH 6 MONTH PRELIMINARY DESIGN OF SPECIFIC F-16 CONFIGURATIONS
- INPUT FIRM FUNDING IN FY 81 BUDGET

57K8

RECOMMENDATIONS (CONT'D)

LABS

- ACCELERATE RESEARCH/DEVELOPMENT TO FILL CRITICAL TECHNOLOGY VOIDS
  - DEGRADED AIRFIELD OPERATIONS
  - SITUATION AWARENESS
  - REDUCED IR VULNERABILITY
  - REDUCED RF SAM VULNERABILITY
  - REDUCED LASER SAM VULNERABILITY
  - NON COOPERATIVE TARGET I.D.

58K8

RECOMMENDATIONS (CONT'D)

ASD

- INITIATE DEVELOPMENT OF KEY TECHNOLOGY OPTIONS SUITABLE FOR F-16
  - RADAR IMPROVEMENTS
  - FLIR POD
  - WFOV/VIDEO HUD
  - ADV LASER DESIGNATOR POD
  - TACTICAL SITUATION DISPLAY
  - ALTERNATE EPU

AFSC

- CLEARLY IDENTIFY A/C INTEGRATION TASKS, FUNDS, SCHEDULES, & RESPONSIBILITIES FOR CURRENT DEVELOPMENT PROGRAM CANDIDATES FOR F-16
  - JTIDS
  - GPS
  - IECM
  - AMRAAM
  - ENGINE DIAGNOSTICS
  - JAM RESISTANT UHF
- SUPPORT F-16 INITIATIVES WITH APPROPRIATE DIRECTION/FUNDING

40A9

FLIR POD

- AUSTERE FLIR POD - FLIR ONLY
  - TWO (OR THREE) FIELDS OF VIEW (POINTABLE)
  - LIMITED FIELD OF REGARD
- LARGE FIELD OF REGARD FLIR AND LASER DESIGNATOR/RANGER
  - TWO (OR THREE) FIELDS OF VIEW (POINTABLE)
  - LOWER HEMISPHERE PLUS 10° LOOK-UP FIELD OF REGARD
- OTHER OPTIONS
- ALL OPTIONS TO HAVE WIDE FIELD OF VIEW (ABOUT 20°) FOR NIGHT PRESENTATION ON A RASTER HUD

41A9

RASTER HEAD-UP/CRT DISPLAY

- AN INCREASED INSTANTANEOUS FIELD OF VIEW PILOT DISPLAY UNIT
  - COMPATIBLE WITH DISPLAY OF STROKE WRITTEN SYMBOLOGY IN DAY ENVIRONMENT
  - COMPATIBLE WITH DISPLAY OF RASTER/STROKE WRITTEN SYMBOLOGY AT NIGHT
  - FORM/FIT INSTALLATION IN COCKPIT
- SEPARATE CRT DISPLAY
  - FUNCTIONALLY LOCATED STORES CONTROL PANEL REPLACEMENT CHIN-UP FORM/FIT INSTALLATION

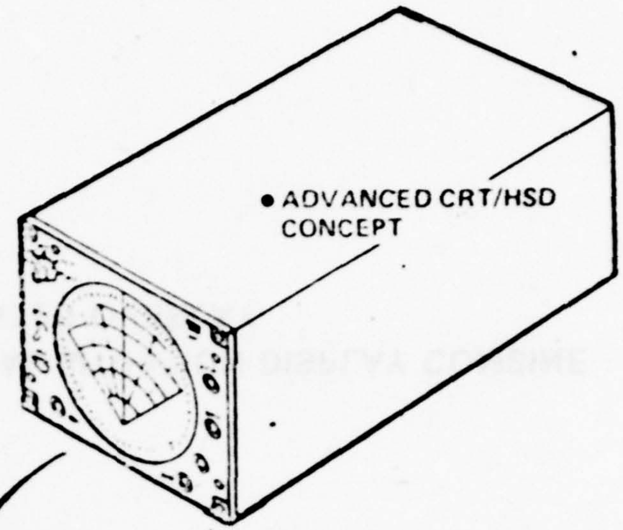
42A9

JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM

- TERMINAL PROVIDES
  - THREAT/TARGET DATA
  - COMMAND AND CONTROL MESSAGES
  - RELATIVE NAVIGATION
- TRANSLATES INTO F-16 IMPROVED CAPABILITY
  - THREAT WARNING
  - NAVIGATION
  - SENSOR CUEING
  - PASSIVE INTERCEPT
  - ANTI-JAM VOICE COMMUNICATIONS

TACTICAL SITUATION DISPLAY

- ADVANCED CATHODE RAY TUBE AND HORIZONTAL SITUATION DISPLAY CONCEPT
  - ✓ Combines a Moving Map Feature with a CRT Generated Overlay
    - *Redundant Multipurpose Display*
    - *Programmable Flexibility for Growth*
  - ✓ Provides a Dynamic Pictorial Display of Present, Past and Future Position
  - ✓ Symbology Overlay Feature for
    - *JTIDS*
    - *GPS*
    - *PLSS*



- ADVANCED CRT/HSD CONCEPT

- MAP DISPLAY WITH SYMBOL OVERLAY (Typical)

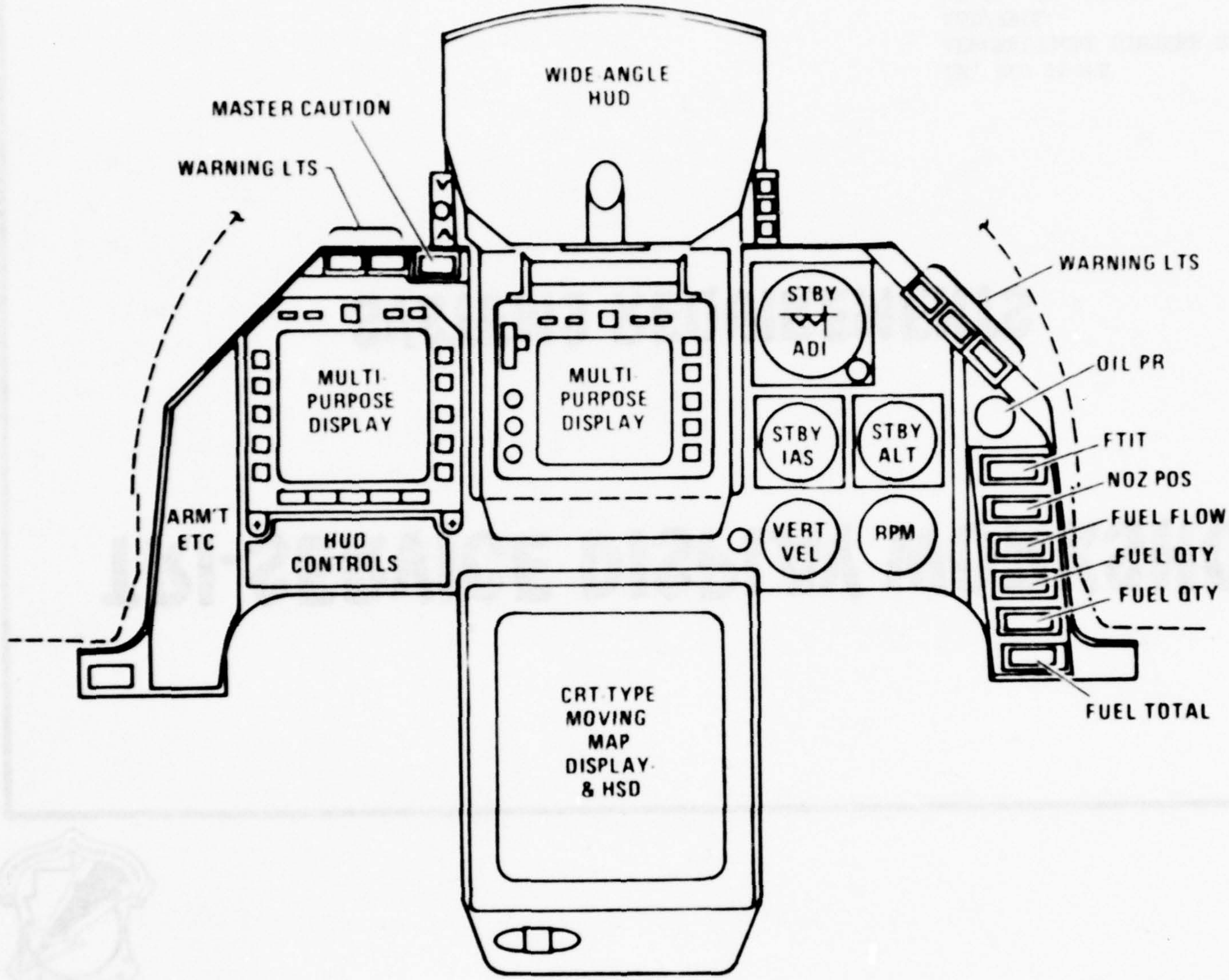
- TYPICAL MAP DISPLAY

43A9

TACTICAL SITUATION DISPLAY

- CATHODE RAY TUBE/HORIZONTAL SITUATION DISPLAY COMBINE MOVING MAP FEATURE WITH CRT GENERATED OVERLAY
- LIGHT EMITTING DIODE ARRAY/HORIZONTAL SITUATION DISPLAY COMBINE MOVING MAP FEATURE WITH LED GENERATED OVERLAY
- OTHER OPTIONS

DISPLAY OPTIONS



TRI-SERVICE DISPLAY WORKSHOP

SYSTEMS REQUIREMENTS

DR. ROY FRICK
AERONAUTICAL SYSTEMS DIVISION
ASD/XRCL
WPAFB, OH 45433

Session II - Systems Requirements

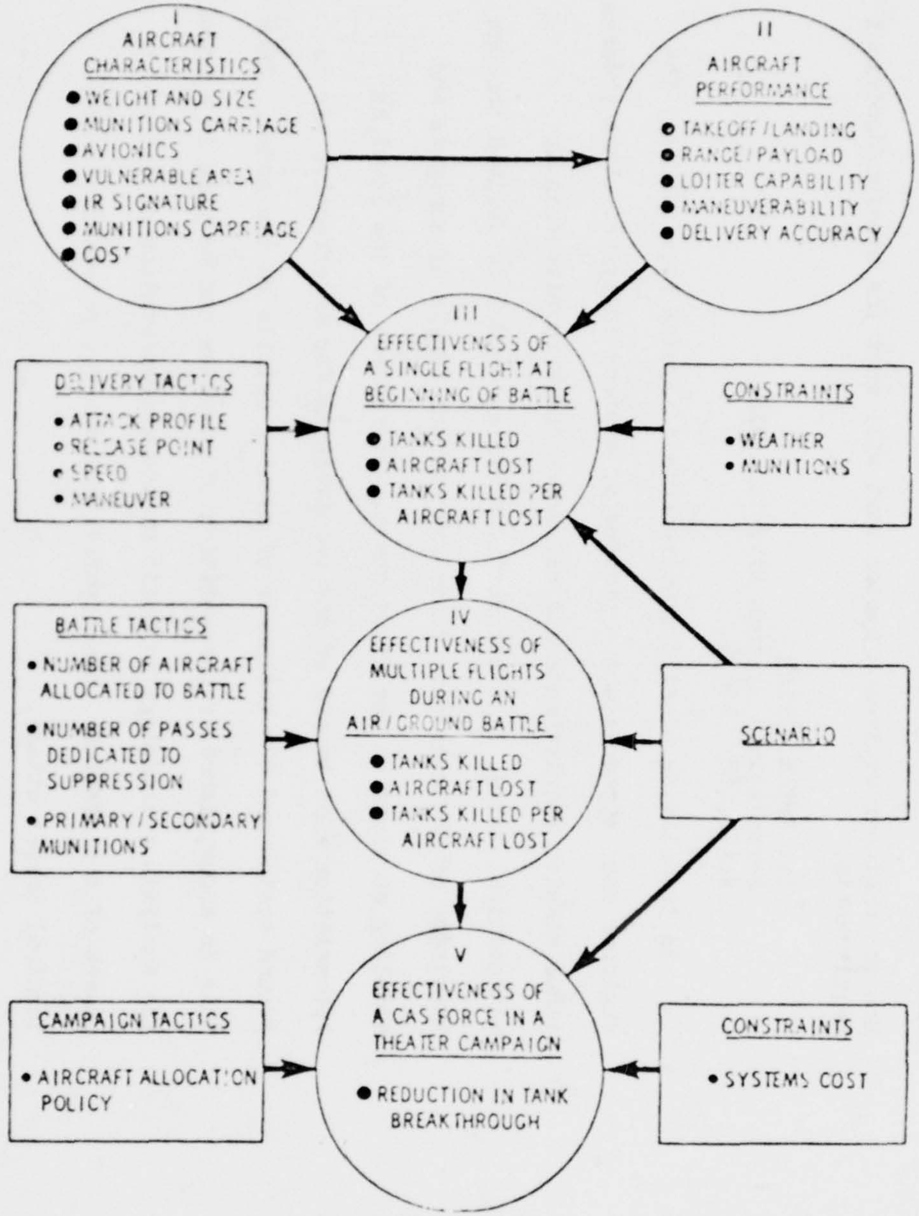
How the engineer evolves a system that will meet the mission/doctrinal requirements.

Dr. Roy K. Frick
Aeronautical Systems Division (XRO)
WPAFB, OH 45433

In translating mission requirements to system requirements, the engineer must appreciate the process of systems analysis. This process takes mission requirements and expresses these requirements in mathematical terms, in other words, a systems model is derived through knowledge of the mission. There are various levels of analysis and modeling as shown on the first chart. Regardless of the level, an appreciation must be had of the requirements for an effective air to ground system and the influence of mission details on the model. Once this is accomplished, representation of a system can be made in a model. The analysis methodology is built on the representation of different phases of the mission: base operations, cruise, penetration, and terminal target attack.

The latter charts show how the mission requirements were translated into system requirements for one vs two seat target acquisition/weapon delivery.

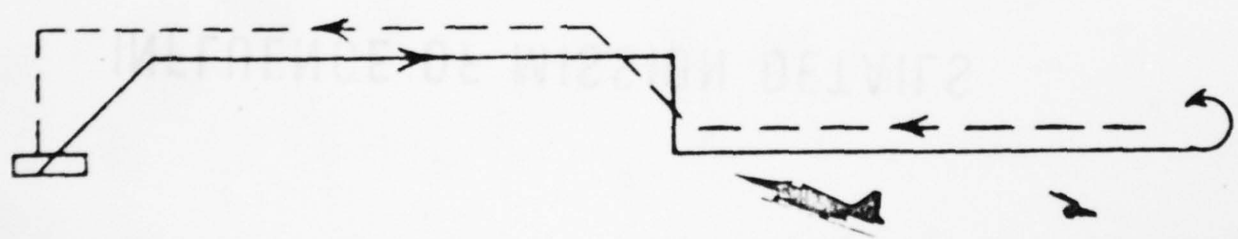
THE FIVE LEVELS OF COMPARISON



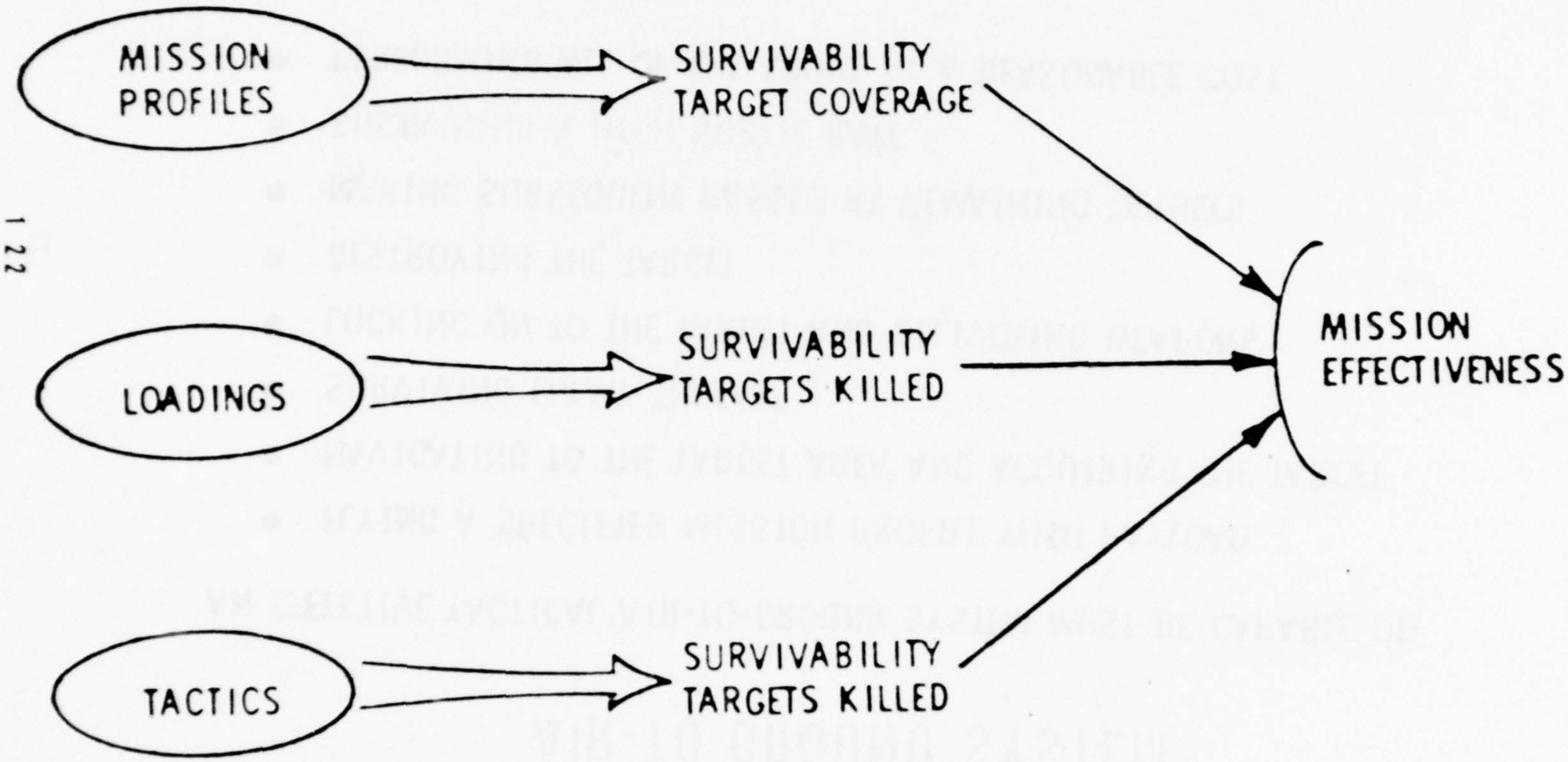
REQUIREMENTS FOR AN EFFECTIVE TACTICAL AIR-TO-GROUND SYSTEM

AN EFFECTIVE TACTICAL AIR-TO-GROUND SYSTEM MUST BE CAPABLE OF:

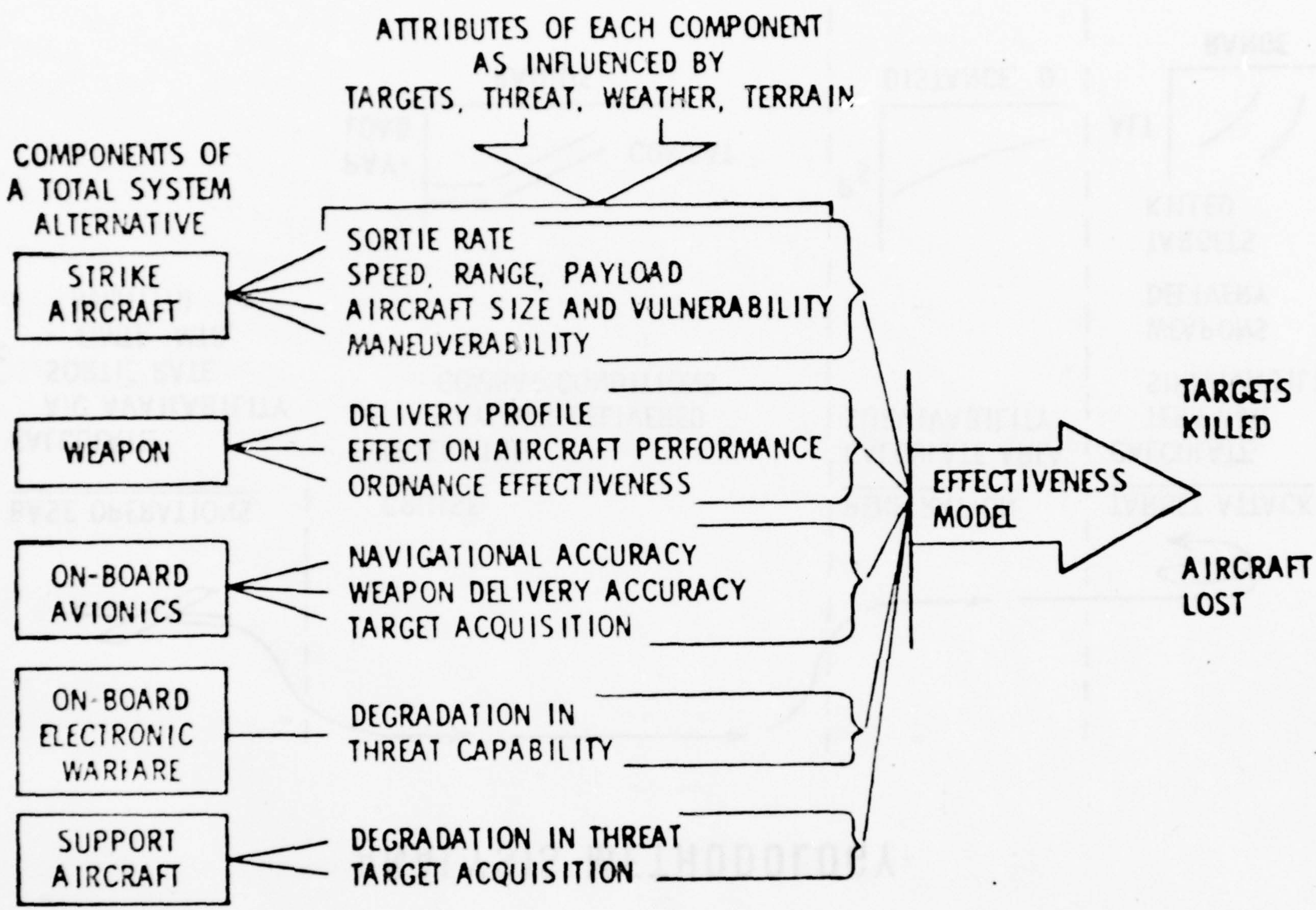
- FLYING A SPECIFIED MISSION PROFILE WITH PAYLOAD
- NAVIGATING TO THE TARGET AREA AND ACQUIRING THE TARGET
- SURVIVING ENEMY THREATS
- LOCKING ON TO THE TARGET AND DELIVERING WEAPONS
- DESTROYING THE TARGET
- MAKING SUBSEQUENT PASSES AT REMAINING TARGETS
- SUSTAINING A HIGH SORTIE RATE
- PERFORMING ALL OF THE ABOVE AT A REASONABLE COST



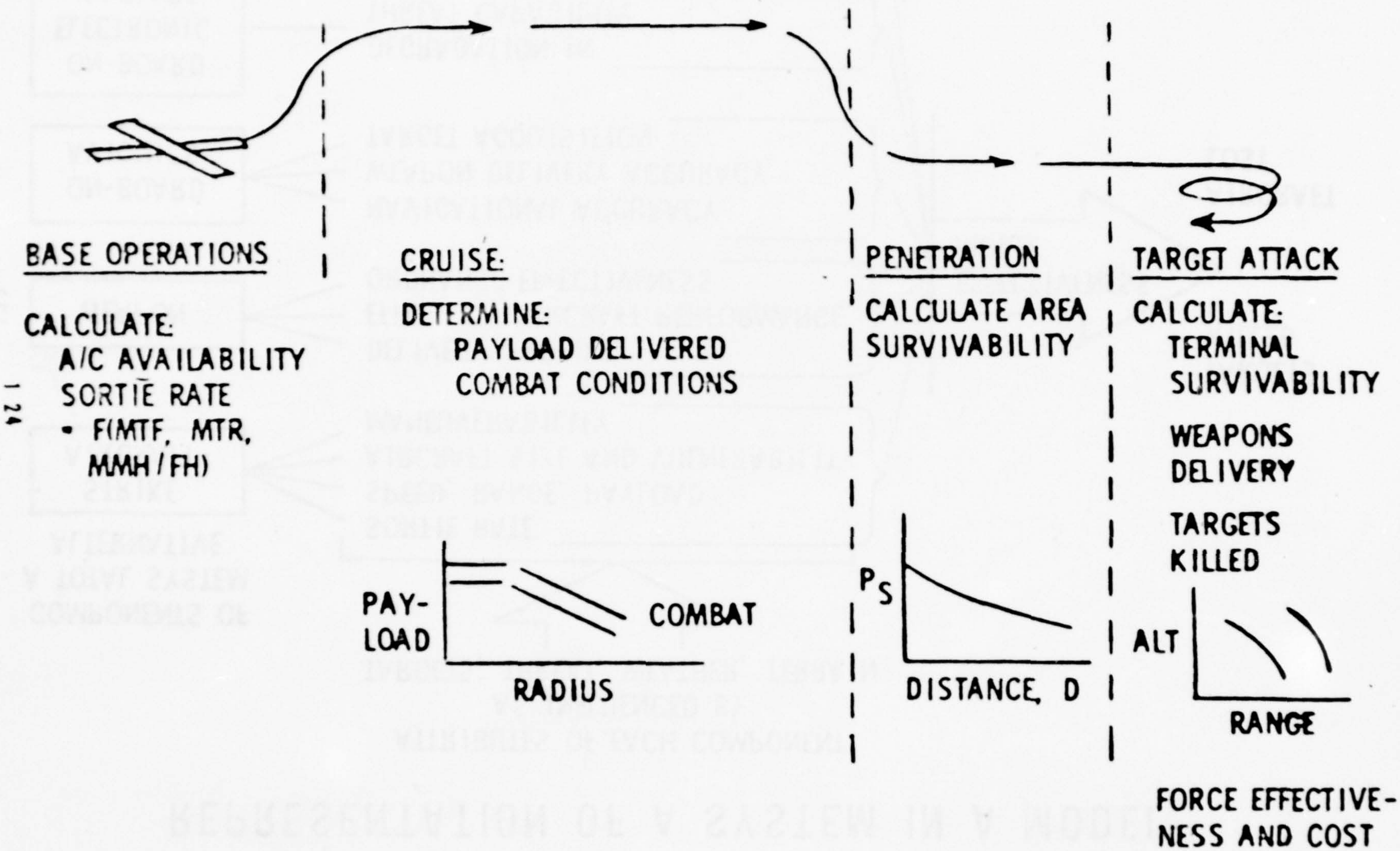
INFLUENCE OF MISSION DETAILS



REPRESENTATION OF A SYSTEM IN A MODEL



ANALYSIS METHODOLOGY



One versus Two Seat Target Acquisition and Weapon Delivery.

Contract No F33615-78-C-01[illegible]
Sponsor ASD/XRO[illegible]
December 197[illegible]

Stephen Howe Consultants Inc.

STUDY APPROACH

This study is conceived as a two part programme. The current phase, which is being reported on, represents the analytic part. This we anticipate will be followed by a second, test and evaluation (T&E) phase.

The approach taken to perform the initial study was to divide it into six activities.

1) Data gathering – from literature and informed sources in US, UK and NATO.

2) System Definition – resolving any ambiguities in the definition of the baseline missions, environments and system.

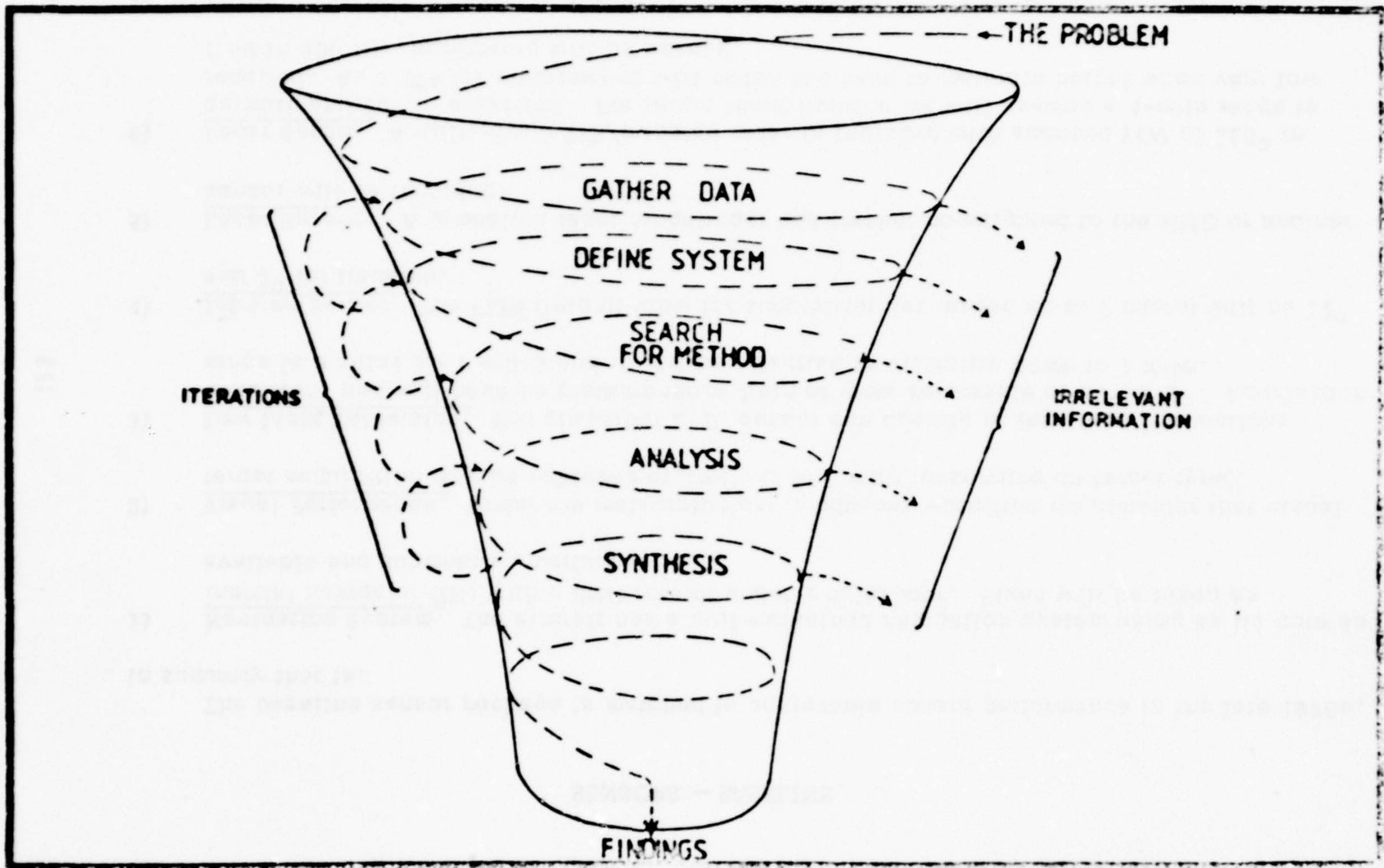
3) Search for a Method – the adaption of our previous analytic tools to this study problem.

4) Analysis – the processing of information through the various analytic elements to produce candidate "stress points" for alleviation.

5) Synthesis – the welding together of consistent systems that embody technological enhancements.

6) T&E Planning & Findings -

STUDY APPROACH



SENSORS – BASELINE

The baseline sensor package is matched to achievable sensor performance in the late 1970s, in summary that is:

1) Navigation System. The aircraft has a self-contained navigation system using as its core an inertial navigator (IN) with a drift rate of under 1 mile/hour. Fixes will be taken as available and augment its performance.

2) Visual Performance. Under the meteorological conditions specified we consider that visual target acquisition may be achieved at upwards of 1 mile (depending on target type).

3) Low Light Television. The gimballed LLTV sensor can operate in less than $\frac{1}{4}$ moonlight conditions and will have an instantaneous field of view selectable at 20° or 3°. Acquisition range is 3 miles for $P = 0.5$ and it will be effective in visibility down to 1 mile.

4) Infrared Sensor. The FLIR field of view for acquisition (at ranges up to 2 miles) will be 12° and 3° for tracking.

5) Laser Sensor. A gimballed laser rangefinder and tracker boresighted to the HUD or another sensor will be included.

6) Radar Sensor. A multi-mode TFR/mapping radar is included with scanned FOV of $\pm 60^{\circ}$ in azimuth and 20° in elevation. For target identification we will assume a 4-mile range is required. As a TFR its performance will match the need to maintain height when very low (100 to 300 ft); monitoring will be needed.

7) Electronic Support Measures (ESM). A passive system is included, scanning all the currently active radar bands. It can identify, in real time, specific threats.

8) ECM. Automatic countermeasures will be deployed (unless overridden by the crew). Chaff or flares could be dispensed and/or ECCM activated.

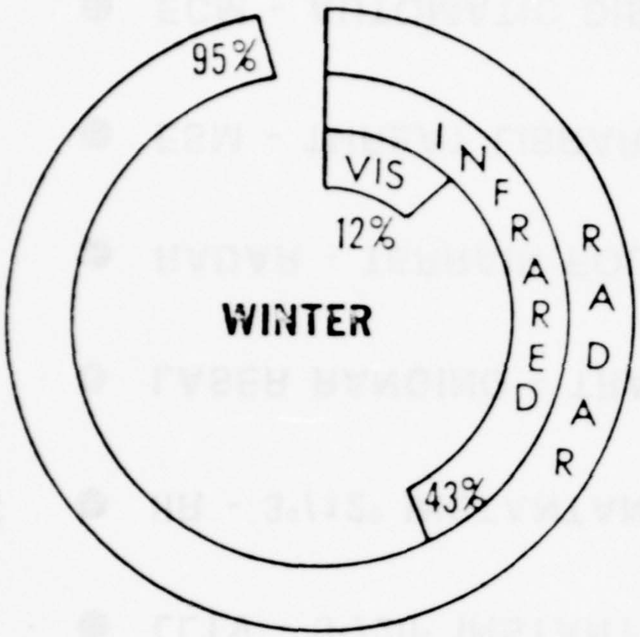
SENSORS - BASELINE

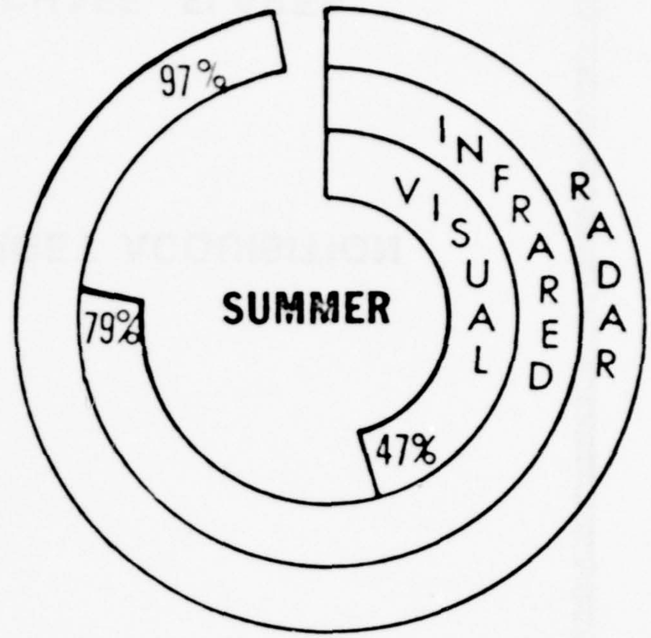
- IN NAVIGATION - 1 MILE/H DRIFT
- LLTV - 3°/20° INSTANTANEOUS FOV
- IIR - 3°/12° INSTANTANEOUS FOV
- LASER RANGING - TRACKING
- RADAR - TERRAIN FOLLOWING /TARGET ACQUISITION
- ESM - THREAT LIBRARY
- ECM - AUTOMATIC DISPENSING OF CHAFF, FLARES

F NSIVE
IR
UPPORT

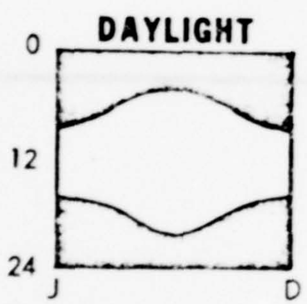
ENVIRONMENTAL CONSTRAINTS ON SENSORS

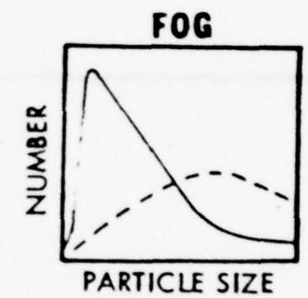
GERMANY





VISUAL: GREATER THAN 3000/3, DAYLIGHT
INFRARED: GREATER THAN 3000/1, ALL HOURS
RADAR: GREATER THAN 100/¼, ALL HOURS





CREW STATION – BASELINE

The configuration assumes a single seat aircraft. It recognises the attributes of current-day systems e.g. F-14A, Tornado, A-10.

Systems available to the pilot, and relevant to the study, are:

1) Multi-mode/sensor head down displays (HDD) of both vertical and horizontal data.

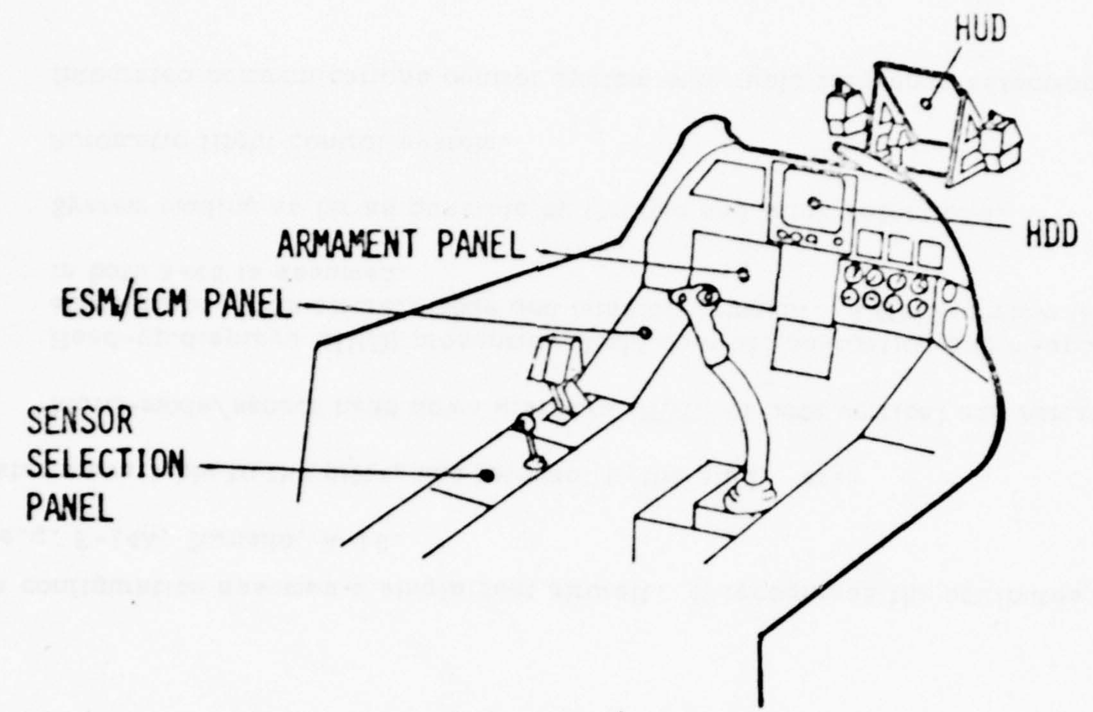
2) Head-up displays (HUD) presenting flight control, navigation and weapon aiming data appropriate to the aircraft mode and mission segment. A field of view (FOV) of $\pm 12^{\circ}$ in both axes is assumed.

3) System moding as far as possible by throttle and stick selections.

4) Automatic flight control system.

5) Integrated communications control system with rapid frequency selection.

CREW STATION - BASELINE



OPERATIONAL AND WEATHER IMPACTS ON TECHNOLOGIES

THE EUROPEAN AIR-TO-GROUND MISSIONS ALL REQUIRE LOW-LEVEL, WEAPON DELIVERY TO BE EFFECTIVE THE PRIMARY REASON IS SURVIVABILITY THROUGH THE TERMINAL PHASE. AS A CONSEQUENCE, THE STUDY IS LOS-LIMITED RATHER THAN SENSOR-LIMITED (SINCE RANGE/RESOLUTION ATTRIBUTES ARE NOT SO CRUCIAL).

WEATHER DOES POSE PROBLEMS, ESPECIALLY IN THE PRECEDING PENETRATION PHASE, BUT IN LOW-LEVEL WEAPON DELIVERY IT IS LESS SERIOUS. VISUAL ACQUISITION AND IR SENSOR PERFORMANCE WOULD, HOWEVER, BE SERIOUSLY DEGRADED IF HIGHER LEVEL MISSIONS WERE CONTEMPLATED.

WHEN ACQUISITION IS MADE THE SPEED AND ACCURACY WITH WHICH THE TARGET IS DESIGNATED TO THE AIRCRAFT SYSTEM IS CRUCIAL: ONLY SECONDS MAY BE AVAILABLE PRIOR TO WEAPON RELEASE. FURTHERMORE, THE TARGET PERFORMANCE MUST BE GOOD AND RELIABLE. IT IS THOSE ON-BOARD CREW FACILITIES, AND THEIR DEPENDENT FUNCTIONS, THAT THE ANALYSIS WILL EXPLORE.

THE CONSEQUENCES OF THESE FACILITY ENHANCEMENTS SHOULD BE CONSIDERED WITHIN THE CONTEXT OF CREW WORKLOAD. MORE DIFFICULT MISSIONS MIGHT THEN BE PRACTICABLE WITH A ONE MAN CREW.

OPERATIONAL AND WEATHER IMPACTS ON TECHNOLOGIES

- LOW ALTITUDE OPERATION ⇨ TARGET ACQUISITION IS LINE OF SIGHT LIMITED RATHER THAN SENSOR LIMITED
- WEATHER (LOW CEILING & VISIBILITY) IS LESS A CONSTRAINT ON LOW ALTITUDE OPERATIONS THAN ON HIGH ALTITUDE OPERATIONS
- THE USE OF SENSORS IS MORE AN ISSUE THAN THE PERFORMANCE OF SENSORS
- PRIORITY IN TECHNOLOGY SOLUTIONS SHOULD BE IN ALLEVIATING WORKLOAD RATHER THAN IMPROVING TARGET ACQUISITION

ANALYTIC METHOD

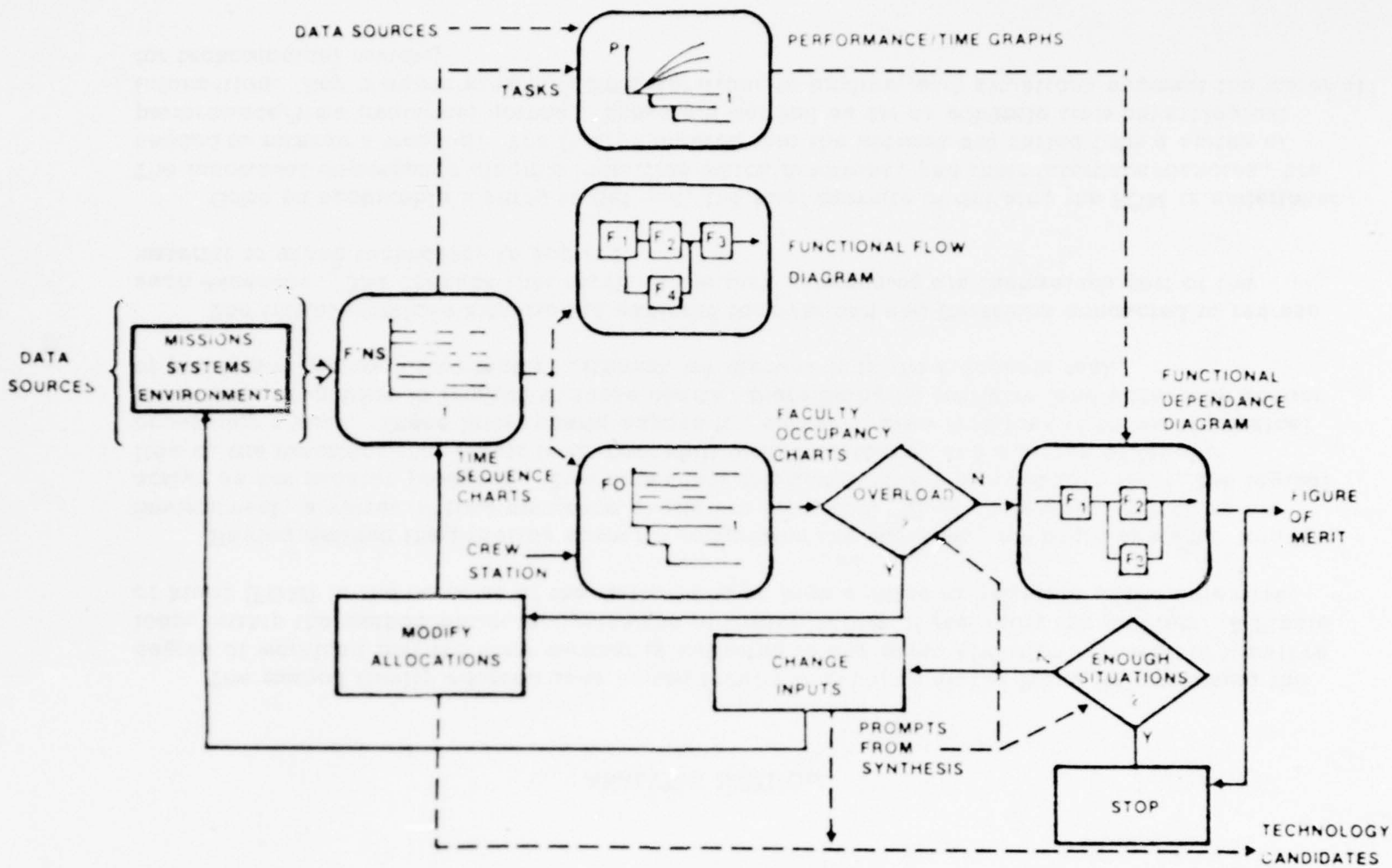
The method finally adopted uses human faculty occupancy as the focus for assessing the degree of workload that the crew member is suffering in any given situation. There are iterative loops within the method which recognise the recursive nature of resolving the problem. A Figure of Merit (FOM) is the outcome of the method and as high a value as possible is the objective.

Having defined the baseline scenario comprising the missions, on-board systems, and the environment, a series of time sequence charts are produced. They show which functions are active as the mission proceeds. Two dependent relationships are derived from this; the logical flow of the functions that result in (successful) weapon release, and a series of faculty occupancy charts. These latter charts expose the extent of crew workload in terms of physical faculties. Cognition is implied in these charts, there being no realistic (and accepted) manner of presenting the cognitive factor, although we discuss it in the synthesis task.

The initial workload situation is explored for overload and iterations conducted to redress such excesses. The changes that result in the task sequencing are themselves part of the material to which technology is applied.

Once an acceptable loading is defined, the final activity of defining the FOM is undertaken. The functional dependence diagram identifies which functions, and their interdependencies, are needed to release a weapon. The figures entered into the network are called from a series of performance/time (resource) graphs. These are derived as far as possbile from physiological information. Any changes stemming from iterations to explore more situations augment the material for technological review.

ANALYTIC METHOD



CURRENT FINDINGS

The consequences of the work performed to date are highlighted. We are conducting more sensitivity analyses that are likely to modify and augment these initial findings. They will be reported on in the final report.

Thus far, our findings are:

1) The missions will be conducted at low level for tactical and defensive reasons. Line of sight (LOS) limitations due to height and terrain masking are more restrictive than sensor performance or weather.

2) Target glimpse times will be brief with the short LOS. It follows that facilities to assist the crew take best advantage of that limited period, e.g., by target recognition software, are more important than sensor performance itself.

3) During the terminal phase the display cursors will be slewed and repositioned a number of times. Improving the ease of use of this process will materially reduce the attendant workload.

4) Monitoring of the ESM and the response to warnings requires continual attention. Improvement could be made in the quality of threat assessment and by video repertoire of countermeasures, e.g., by taking account of the aircraft's position before deployment.

5) The target designation task could be the best candidate for the application of more resource in time or technology terms; the sensitivity analysis exposed this factor and further assessments should confirm this.

6) Everytime the pilot transfers attention from outside to inside the cockpit, an adaptation period is needed. If the number of transfers can be reduced, by system reconfiguration, that "dead-time" can be better used.

7) With a given tank combination one pair of facilities require more cognitive resources than another, e.g., hand & hand versus hand & voice pairing. The use of appropriate combinations can be aided by technology.

CURRENT FINDINGS

1. SCENARIO IS LOS-LIMITED
2. IMPROVE CREW FACILITIES, NOT SENSORS
3. REDUCE CURSOR SLEWING WORKLOAD
4. REDUCE SELF-DEFENSE WORKLOAD
5. HIGHEST PAYOFF IS TO IMPROVE TARGET DESIGNATION
6. RECONFIGURE CREW FACILITIES TO REDUCE DEAD-TIME
7. RECOGNIZE VALUE OF MINIMUM INTERFERENCE FACULTY COMBINATIONS

PROMISING SYSTEM CONFIGURATIONS

We have shown those system configurations; two one seat and one two seat. They could use current or near-term technology. They were selected to expose two extreme cases, all head-up and all head-down. Further configurations and reassessments will be developed in the final report.

Either one-seat system satisfies a number of the findings identified previously. Dead-time is reduced in the head-up system by presenting flight control, navigation and compatible (i.e., 1:1 with outside world) sensor data on the head up display (HUD). Non-compatible data could be presented head-up as a collimetered image (as on the HUD) onto a screen, for example, by the side of the HUD. The time now made available, previously used to adapt from in- to *outside-cockpit viewing*, can be productively used directly on the terminal phase tasks.

Likewise, the head-down system places emphasis on flight control, etc., information appearing on a held-down display (HDD).

The use of direct voice instructions (DVI) or helmet mounted sight (HMS) offers the benefit of minimum interference between simultaneous use of facilities e.g., flight control and cursor slewing.

Adaptable countermeasures offer the opportunity to increase the repertoire of threat responses, say by optimizing them to aircraft flight path. Their enhanced utility would reduce crew stress and thus workload.

The trade off in the two-man system is technology vs. man, consequently the former is not so evident.

PROMISING SYSTEM CONFIGURATIONS
CURRENT AND NEAR-TERM TECHNOLOGIES

1 SEAT

1. HEAD UP CONCEPT
   - USE DVI OR HMS FOR TARGET DESIGNATION
   - PRESENT COMPATIBLE SENSOR DATA ON HUD
   - PRESENT NON-COMPATIBLE DATA HEAD-UP
   - PROVIDE ADAPTABLE COUNTERMEASURES
2. HEAD DOWN CONCEPT
   - USE DVI OR HMS FOR TARGET DESIGNATION
   - PRESENT VSI AND FLIGHT CONTROL DATA HEAD-DOWN
   - PROVIDE ADAPTABLE COUNTERMEASURES

2 SEAT

PILOT

- AS 1 SEAT HEAD UP CONCEPT (LESS DVI AND HMS)

SYSTEMS OPERATOR

- PROVIDE ADAPTABLE COUNTERMEASURES

SUMMARY

1. TITLE: THE PM ROLE IN THE EVOLUTION OF THE TADS/PNVS DISPLAYS.

2. NAME/TITLE OF PRESENTER: COLONEL C. A. PATNODE, JR.
TADS/PNVS PROJECT MANAGER

3. ADDRESS: TADS/PNVS PROJECT MANAGER'S OFFICE
ATTN: DRCPM-AAH-TP
USADARCOM
PO BOX 209
ST. LOUIS, MO 63166

4. TELEPHONE: AUTOVON 698-3995/5673
COMMERCIAL 314-268-3995/5673

5. PRESENTATION:

THE ARMY'S CONTINUING INTEREST IN A BETTER WAY TO KILL TANKS--DAY AND NIGHT, AND DURING ADVERSE WEATHER--HAS BEEN SUPPORTED BY A NUMBER OF EXPLORATORY DEVELOPMENTS. CONCURRENT WITH THESE DEVELOPMENTS THE USER (US ARMY TRAINING AND DOCTRINE COMMAND, TRADOC) WAS PREPARING REQUIREMENTS FOR SYSTEMS TO MORE EFFECTIVELY ACCOMPLISH THIS MISSION. THE MELDING OF THESE PARALLEL EFFORTS, TECHNICALLY FEASIBLE SYSTEMS TO SATISFY MISSION REQUIREMENTS, PRODUCES REQUIREMENTS DOCUMENTS FOR GENERIC SYSTEMS OR SUBSYSTEMS.

IT IS AT THIS STAGE THAT A PROJECT MANAGER DESIGNEE BEGINS PREPARING A DETAILED DEVELOPMENT PLAN FOR A GENERIC SYSTEM TO MEET THE USER'S REQUIREMENT. A SERIES OF DEVELOPMENT MILESTONES WILL BE BRIEFLY COVERED.

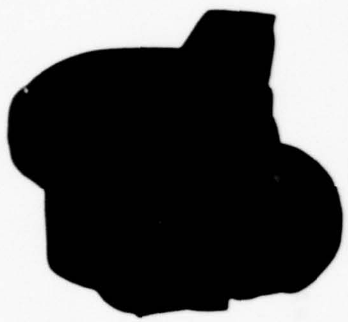
THE DEVELOPMENT AND RELEASE TO INDUSTRY OF A REQUEST FOR PROPOSAL (RFP) THAT DETAILS THE REQUIRED GENERIC SYSTEM IN A SPECIFICATION, AS WELL AS THE TOTAL CONTRACTUAL REQUIREMENTS FOR TECHNICAL PERFORMANCE, SCHEDULE, AND COSTS NORMALLY SIGNALS THE PROGRAM IS TRULY "OFF AND RUNNING." INDUSTRY RESPONDS TO THE RFP AND A

CONTRACTOR/CONTRACTORS IS/ARE SELECTED FOR THE DEVELOPMENT. THE DEVELOPMENT TEAM IS NOW IN BEING. IN THIS PARTICULAR CASE THIS TEAM IS COMPRISED OF HUGHES HELICOPTERS AS THE PRIME WEAPON SYSTEMS CONTRACTOR, MARTIN MARIETTA AND NORTHROP CORPORATION AS ASSOCIATE CONTRACTORS FOR THIS PARTICULAR SUBSYSTEM, AND THE TADS/PNVS PROJECT MANAGER (PM). THE PM MANAGES THE PROJECT BY COORDINATION AND DIRECTION OF ALL RELATED GOVERNMENT ACTIVITIES AND ADMINISTERS THE INDUSTRY CONTRACTS.

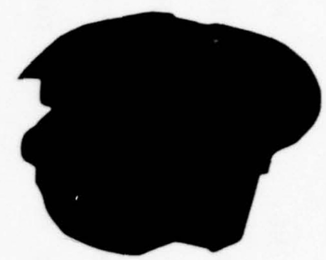
THE CONTRACTOR DEVELOPS SYSTEM CHARACTERISTICS AND FROM THEM GENERATES A CONTRACTOR SPECIFICATION TO MEET THE REQUIREMENTS OF THE GOVERNMENT SPECIFICATION. UPON GOVERNMENT APPROVAL OF THEIR SPECIFICATION AND DESIGN, THE CONTRACTORS INITIATE THE FABRICATION AND ASSEMBLY OF HARDWARE.

IN ORDER TO SUBSTANTIATE THAT THE HARDWARE DOES MEET THE SPECIFICATIONS, THE CONTRACTOR AND THE GOVERNMENT VIGOROUSLY TEST THE HARDWARE, BOTH ON THE GROUND AND INFLIGHT, AT VARIOUS LEVELS SUCH AS COMPONENT, SUBSYSTEM, AND SYSTEM. THE GOAL IS TO OBTAIN SUFFICIENT DATA IN ORDER TO VERIFY THE PERFORMANCE OF THE SYSTEM AND TO SELECT A PRODUCTION CONTRACTOR.

U.S. ARMY
ADVANCED ATTACK HELICOPTER
AAH



MARTIN MARIETTA



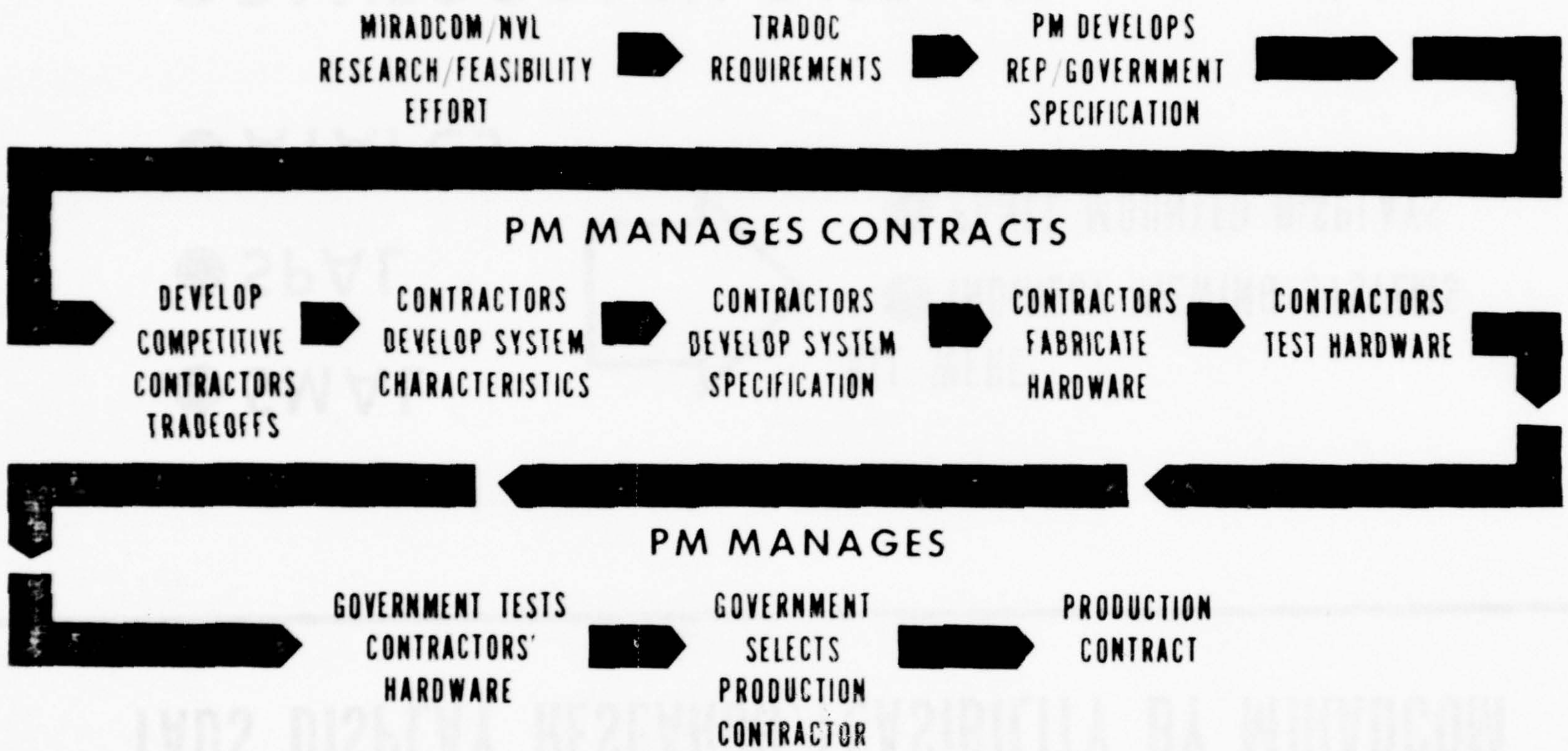
NORTHROP

TADS/PNVS PROGRAM

COL C.A. PATNODE JR.

TADS/PNVS PROJECT MANAGER

THE PM ROLE IN EVOLUTION OF TADS/PNVS DISPLAYS



TADS DISPLAY RESEARCH/FEASIBILITY BY MIRADCOM

- SMAL
- SPAL
- ATAFCS

ALL WERE:

- INDIRECT VIEWING SYSTEMS
- PANEL MOUNTED DISPLAYS

- PANTOGRAPH DISPLAY
  - 5 INCH CRT
  - 2 INCH CRT

RESULTS OF PMD TESTING

- PMD SUSCEPTIBLE TO LOSS OF VIEWING CONTRAST
- DESIGN MUST CONSIDER AMBIENT/SUN EFFECTS
- DESIGN MUST CONSIDER PMD EFFECT ON COCKPIT REFLECTIONS
- OPTIMUM VIEWING DISTANCES FROM THE PMD WERE ESTABLISHED

PNVS DISPLAY RESEARCH/FEASIBILITY (43.7 IIA) BY NV&EOL

OPTIC I

- OTAS
- PNVS

PMD

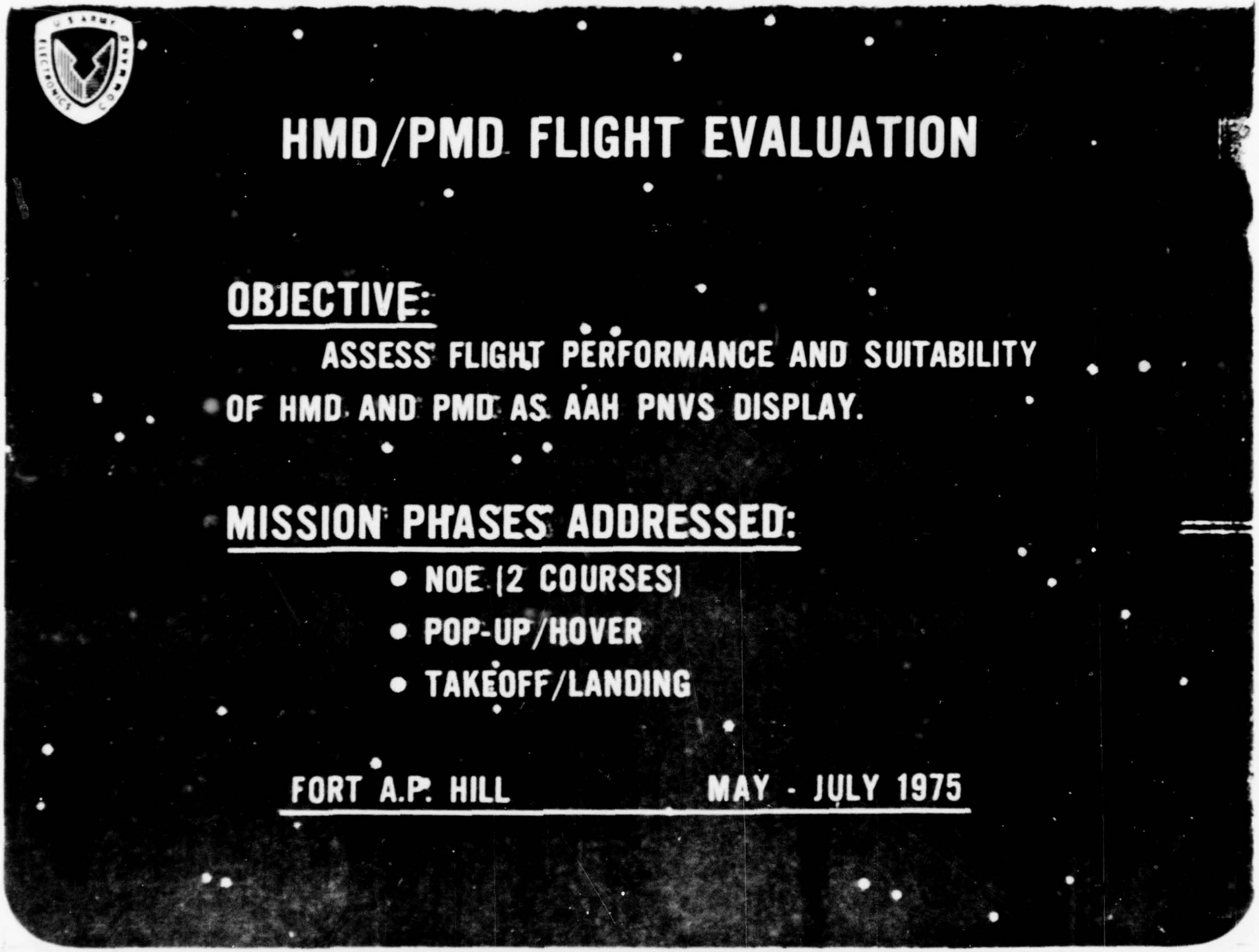
HMD

SYMBOLOGY

HOVER REQUIREMENTS

43.7 IIA NAVIGATION/PILOTAGE SUMMARY

- OTAS NOT USABLE AS NAV AID W/O WIDER FOV.
- PNVS POTENTIAL DEMONSTRATED - FOLLOW UP REQUIRED.
- PILOT PREFERENCE FOR HMD VS. PMD.
- PNVS. SYMBOLOGY ESSENTIAL.
- HOVER AIDE REQUIRED.


U.S. ARMY ELECTRONICS COMMAND
HMD/PMD FLIGHT EVALUATION
OBJECTIVE:
ASSESS FLIGHT PERFORMANCE AND SUITABILITY
OF HMD AND PMD AS AAH PNVS DISPLAY.
MISSION PHASES ADDRESSED:
• NOE (2 COURSES)
• POP-UP/HOVER
• TAKEOFF/LANDING
FORT A.P. HILL
MAY - JULY 1975

PMD

ADVANTAGES

- SUPERIOR (TO HMD) IMAGE QUALITY.

DISADVANTAGES

- HAND SLEW CONTROL INCREASES TASK LOADING.
- OFF AXIS AXIS DISORIENTATION.
- BOTH EYES NOT DARK ADAPTED.
- COCKPIT GLOW.

HMD/HEADTRACKER

ADVANTAGES

- NATURAL FEEL FOR SENSOR ORIENTATION.
- SENSOR SLEWING WITHOUT HAND CONTROL.
- NON—HMD EYE DARK ADAPTED (SURVIVABILITY).

DISADVANTAGES

- RESOLUTION/IMAGE QUALITY LOWER THAN PMD.
- LENGTHY PREFLIGHT BORESIGHT.

EVOLUTION OF TADS

1. INITIALLY - TOW TYPE SIGHT WITH TOW MISSILE SYSTEM, FLIR, AND LASER RANGEFINDER

2. APRIL 1976 - CHANGE TO HELLFIRE REQUIRED CURRENT TADS
   - BETTER STABILIZATION
   - PRECISION DESIGNATION
   - TV SENSOR

EVOLUTION OF PNVS

1. INITIALLY - (A). SWP FOR PROTOTYPES A/C

   (B). INSTALLED ON PRODUCTION A/C

2. DEC 75 - TO BE INSTALLED ON PROTOTYPES FOR DT/OT TESTING PRIOR TO PRODUCTION

DEVELOPMENT OF GOVERNMENT SPECIFICATION

- TADS TECH TEAM
  - MIRADCOM - CHAIRMAN
  - ARRADCOM
  - NVL
  - HEL
  - AVRADCOM
  - AAH PMO
  - HF PMO
- PNVS TECH TEAM
  - NVL - CHAIRMAN
  - MIRADCOM
  - AVRADCOM
  - HEL
  - AAH PMO
  - AVRADA
  - AMRL
- TRADOC

CONTRACTORS DESIGN PHASE TADS/PNVS CONTROLS AND DISPLAYS SYSTEM TRADEOFFS

- MISSION ANALYSIS
- THREAT ANALYSIS
- OPERATIONS ANALYSIS
- OPERATOR TASK ANALYSIS
- TIME-LINE ANALYSIS
- SPECIAL STUDIES (i.e., ANTHROPOMETRICS)
- STATIC MOCK-UP EVALUATIONS
- MODE LOGIC ANALYSIS
- DESIGN TRADEOFFS
- FUNCTIONAL ANALYSIS
- TASK TIME PROFILES
- SYSTEM TRADEOFFS
- LIFE CYCLE COST TRADEOFFS
- SYSTEM EFFECTIVENESS
- RELIABILITY/MAINTAINABILITY/SAFETY

CONTRACTORS
MAJOR TADS/PNVS DISPLAY TRADEOFFS

HEADS-UP DISPLAY TRADEOFFS

- SINGLE CRT
  - PROJECTED IMAGE
  - HIGH GAIN SCREEN
  - FRESNEL SCREEN
  - IMAGE INTENSITY
- TWO CRT'S
  - BIOCULAR
  - PANEL-MOUNTED

ALPHA-NUMERIC DISPLAY TRADEOFFS

- AND DISPLAYED ON CRT OF IVD
- TAPERED FIBER OPTIC BUNDLE AND OFF-THE-SHELF DISPLAY
- DEMAGNIFICATION OPTICS AND OFF-THE-SHELF DISPLAY
- DEMAGNIFICATION OPTICS AND CUSTOM DISPLAY

SYSTEM CHARACTERISTICS DRIVE DISPLAY REQUIREMENTS

TARGET CHARACTERISTICS
- CONTRAST
- SIZE
- COLOR
- ASPECT
- BACKGROUND CLUTTER

ATMOSPHERIC TRANSMISSION
- AEROSOLS
- HUMIDITY
- TURBULENCE
- SMOKE
- RANGE

SENSOR CHARACTERISTICS
- RESPONSIVITY
- OPTICS APERTURE
- FOV
- MTF
- GAMMA
- STABILIZATION
- TRACKING

VIDEO PROCESSING
- BANDWIDTH
- GAMMA CORRECTION
- APERTURE CORRECTION
- SIGNAL TO NOISE RATED

DISPLAY
- COLOR
- MTF DISPLAY SENSOR
- GRAY SCALE
- AMBIENT ILLUMINATION
- CONTROLS - CONTRAST
  - BRIGHTNESS
- GLARE
- SIZE
- BRIGHTNESS RANGE

HUMAN OPERATOR
- EYE RESPONSE
- DISTANCE TO DISPLAY
- FATIGUE
- TASK LOADING
- TRAINING
- SUBJECTIVE FACTORS (DISPLAY COLOR PREFERENCE, ETC.)

DISPLAY TRADES DRIVEN BY SYSTEM REQUIREMENTS RESULT IN DISPLAY SPECIFICATION

SYSTEM REQUIREMENTS

- HOD - HDD
- EYE DISTANCE
- DAY/NIGHT OPERATION
- VISUAL FOV
- SYMBOLOGY COMPATIBILITY
- AMBIENT ILLUMINATION
  - DYNAMIC RANGE (SHORT TERM)
  - TOTAL RANGE

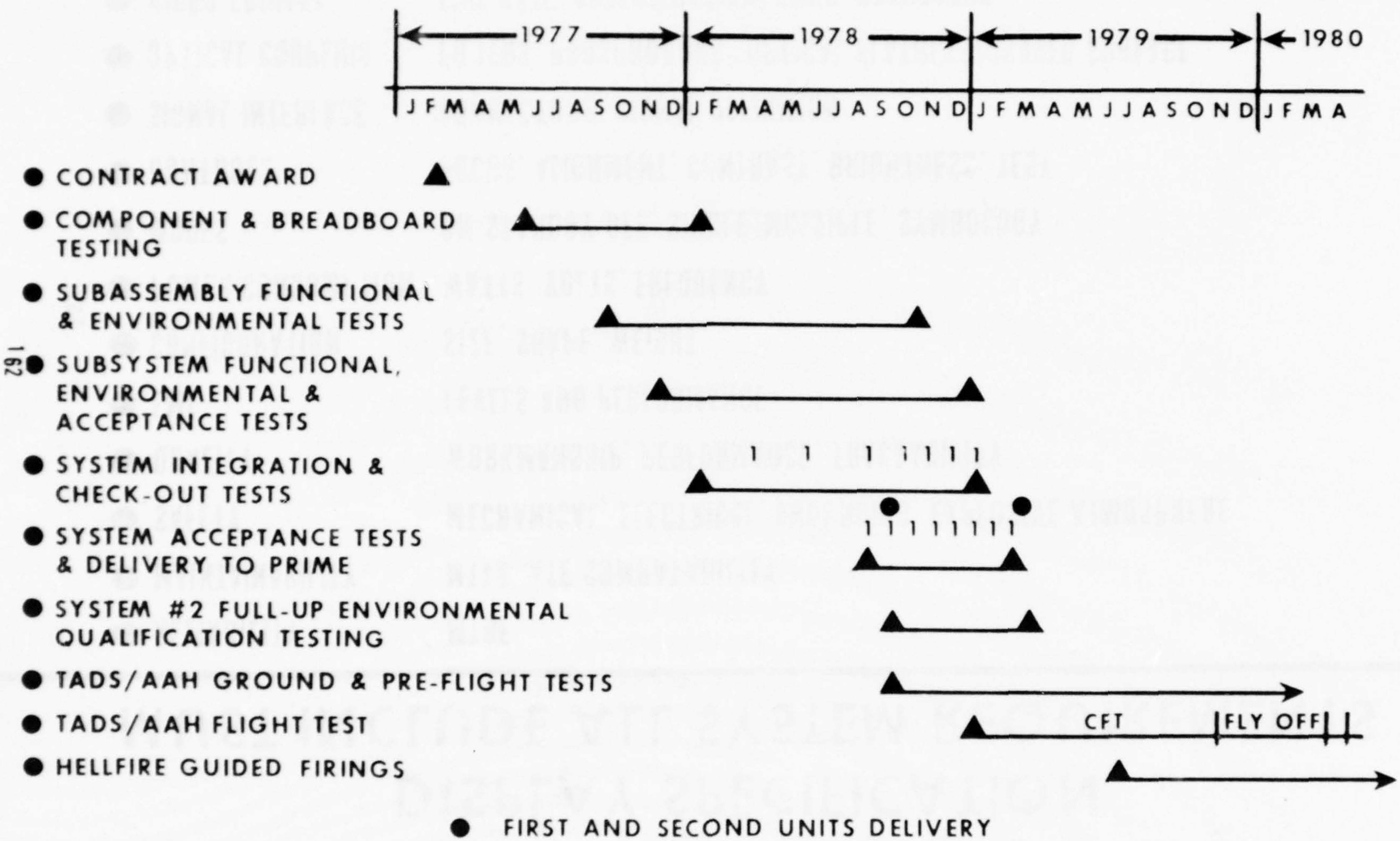
DISPLAY TRADES

- DISPLAY SIZE VS SPOT SIZE VS MTF
- BANDWIDTH VS MTF VS VIDEO PROCESSING
- OPTICAL RELAY - SIZE/WEIGHT - TRANSMISSION
- PHOSPHOR COLOR - FILTER SELECTIONS
- SYMBOLOGY - STROKE WRITING VS RASTER ADDITION - LINE RATE
- GRAY SCALE VS AMBIENT ILLUMINATION
- BRIGHTNESS VS PERFORMANCE
- MONOCULAR VS BINOCULAR VIEWING
- ADAPTION TIME (DISPLAY TO OUTSIDE VIEWING TRANSITION)
- ALLOWABLE HEAD MOVEMENT

DISPLAY SPECIFICATION MUST INCLUDE ALL SYSTEM REQUIREMENTS

• RELIABILITY	MTBF
• MAINTAINABILITY	MTTR, ATE COMPATABILITY
• SAFETY	MECHANICAL, ELECTRICAL, GROUNDING, EXPLOSIVE ATMOSPHERE
• QUALITY	WORKMANSHIP, PERFORMANCE, TRACEABILITY
• EMI	LEVELS AND PERFORMANCE
• CONFIGURATION	SIZE, SHAPE, WEIGHT
• POWER CONSUMPTION	WATTS, VOLTS, FREQUENCY
• MODES	ON-STANDBY-OFF, SINGLE/MULTIPLE, SYMBOLOGY
• CONTROLS	FOCUS, ALIGNMENT, CONTRAST, BRIGHTNESS, TEST
• SIGNAL INTERFACE	CONNECTORS, SIGNAL DEFINITION
• OPTICAL COUPLING	FILTERS, PHOSPHOROUS, OPTICAL FLATNESS/CURVED SURFACE
• VIDEO FORMAT	LINE RATE, ASPECT RATIOS, SYNC STANDARDS
• VIDEO PERFORMANCE	RASTER SIZE, CRT SPOT SIZE, LINEARITY, DISTORTION MTR, BRIGHTNESS, DYNAMIC RANGE, NOISE
• ENVIRONMENT	VIBRATION, SHOCK, TEMPERATURE, QUALIFICATION, REQUIREMENTS

TADS GENERIC TEST SCHEDULE



GOVERNMENT TESTS

TADS/PNVS FLYOFF

↓

OT IIa

↓

OT IIb

↓

PRODUCTION AWARD

Presentation by Lt. T. Mitchell, USN

Sensor Branch, Naval Air Development Center
Warminster, Pennsylvania 18974

Phone: (215) 441-2889

TITLE: Concept Definition of a Night Vision System for USMC Transport Helicopters.

PRESENTED TO: Tri-service Display Workshop, sponsored by the Display Sub Panel on Night Vision Technology, Naval Oceans Systems Center, San Diego, CA on 15 January 1979.

SUMMARY OF PRESENTATION:

1. Night Vision System Requirement for transport helicopter operations in amphibious operations.

2. Description of the analysis leading to concept definition.

   a. Transport helicopter mission description.

   b. Tradeoff analysis.

   c. Measure of effectiveness.

3. System options.

   a. Classes of options.

   b. Display options.

   c. System alternatives.

4. Selection of options.

HELICOPTER NIGHT VISION SYSTEM

CONCEPT DEFINITION STEPS

- OPERATIONAL REQUIREMENT
- MISSION DESCRIPTION
- MOE DEVELOPMENT
- SYSTEM EVALUATION

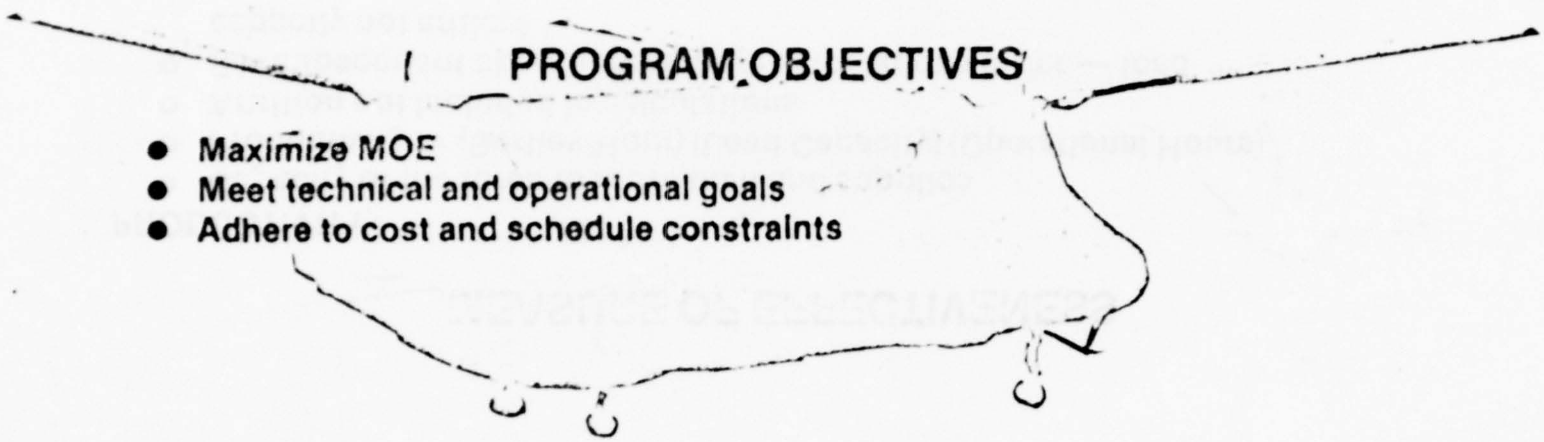
MEASURE OF EFFECTIVENESS

PRODUCTIVITY

- Capacity of the force to move men and supplies
- Productivity = (Sorties/Hour) (Load Capacity) (Operational Hours)
- Attrition not included in calculations
- For subsequent operations ashore calculations differ — load capacity not critical

HNVS

PROGRAM OBJECTIVES



- Maximize MOE
- Meet technical and operational goals
- Adhere to cost and schedule constraints

HNVS

OPTIONS

CLASSES

- Night Vision Goggles (NVG)
- Pyro Electric Vidicon
- Active Gated TV
- Low Light Level Television (LLLTV)
- Imaging Infra Red Devices (IIR)

UNACCEPTABLE

- Cost/Performance
  Pyro Electric Vidicon
  Active Gated TV
  Low Light Level Television

ACCEPTABLE

- Night Vision Goggles
  Developed
  Available In Near Term
  Low Cost
  Performance Not Adequate
- Imaging Infra Red
  Best Capability
  Moderate Cost

HNVS

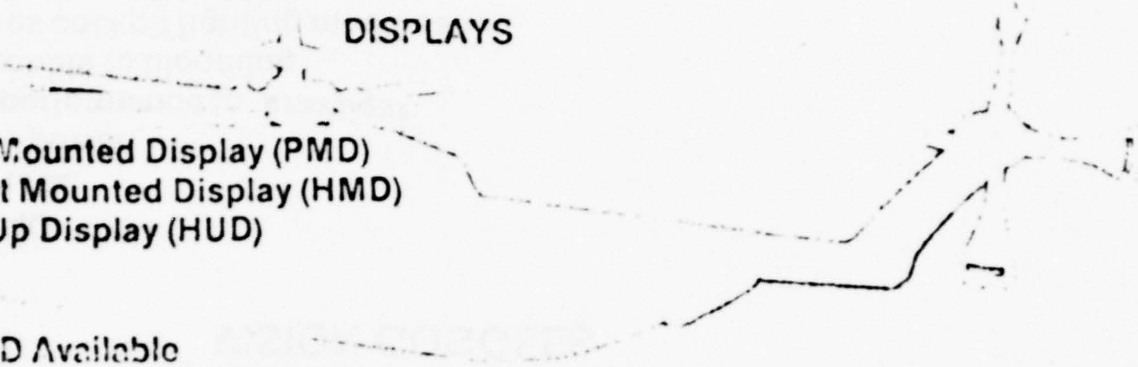
OPTIONS

DUAL SENSORS

- Weight Increase — 80%
- Cost — Significant
- NVG & Single Sensor FLIR
- Provides Similar Capability
- Lower Cost
- Less Complexity

OPTIONS

DISPLAYS



CLASSES
- o Panel Mounted Display (PMD)
- o Helmet Mounted Display (HMD)
- o Head Up Display (HUD)

EVALUATION
- o No HUD Available
- o HMD Not Recommended
- o PMD Selected

HNVS

OPTIONS

3d GENERATION NIGHT VISION GOGGLES

- FOV — 40°
- WT. — 10 oz.

Battery power
Good performance to *starlight*
Susceptible to blooming
Requires cockpit lighting modification
In production (IOC - 1985)

HNVS

OPTIONS

MODIFIED AAS-36 FLIR

- Two FOV 60° x 45°
  15° x 20°
- Demonstrated Reliability — 300 HRS MTBF
- Weight 299-334 lbs.
- Dual Pilot Selectable panel mounted displays.
- Stabilization
- IOC of September 1985

HNVS

FLIR OPTIMIZED FOR TRANSPORT HELICOPTER

- 2FOVs (45° x 60°) (15° x 22°)
- Reliability of 300 HRS MTBF
- WT. 165-285 lbs.
- Dual Pilot selectable panel mounted displays
- Stabilization
- IOC of July 1986

SELECTION OF OPTIONS

- PHASE I

    NIGHT VISION GOGGLES

    - NEAR TERM
    - BACKUP

- PHASE II

    TRANSPORT HELICOPTER FLIR

    - MID TERM
    - MEETS REQUIREMENTS
    - COST EFFECTIVE

SESSION III - HUMAN FACTORS

PSYCHOPHYSICAL CONSIDERATIONS IN DISPLAY DESIGN

By

Frank F. Holly
US Army Aeromedical Research Laboratory
Fort Rucker, AL 36362

Introduction

When the psychophysical aspects of display design are discussed, such factors as contrast ratios and critical flicker frequency are commonly considered. What I wish to discuss today are some factors which receive less frequent attention but also have an impact upon display design. These factors are:

I. EFFECT OF THE SURROUND UPON ACUITY

II. MONOCULAR VS. BINOCULAR ACUITY

III. EFFECT OF TARGET SIZE UPON PERCEIVED VELOCITY

IV. MULTIPLE IMAGING PRODUCED BY SACCADIC EYE MOVEMENTS

I. EFFECT OF THE SURROUND UPON ACUITY

The first slide shows a type of acuity test which is currently used quite frequently in vision research. The bars have a sinusoidal brightness distribution which gives them a "fuzzy-edged" appearance. The observer's task is to adjust the contrast to the point where the bars can just be seen. This is done for different spatial frequencies (bar widths) and the contrast sensitivity (inverse of the threshold modulation) is plotted as a function of spatial frequency. A typical such function is shown in Figure 1 (Campbell and Maffei, 1974). Figure 2 shows for a limited range of frequencies the effect of various surrounds upon this function (Estevez and Cavonius, 1976). Performance is best with a uniform surround which matches the average luminance of the bar pattern (+). A uniform surround is also used in the second function (o). However, here a 12' black line surrounds the bar pattern separating it from the uniform surround. It can be seen that adding this line degrades the performance. The poorest performance is produced by the completely dark surround (□). This reduction in contrast produced by a dark surround has long been known to television and photographic engineers, and some designers routinely use a gamma (which is the ratio of display log contrast to scene log contrast) of from 1.3 to 1.5 to compensate for this apparent loss of contrast when a scene is displayed in a dark surround.

It is also known that the surround effects occur with more standard acuity tests, i.e., tests which use high contrast targets and determine the minimum angle resolvable. For example, Lythgoe (1954) showed that a dark surround reduces acuity for high contrast targets and Flom, Weymouth, and Kahneman (1963) found that acuity is reduced when lines are placed near a Landolt ring. Figure 3 shows the performance in terms of angular separation and Figure 4 shows the same thing in terms of linear separation.

II. MONOCULAR VS. BINOCULAR ACUITY

We can also discuss the effects of monocular vs. binocular viewing in terms of the two types of acuity tests. Horowitz (1949) found that the minimum angle resolvable with high contrast targets is from 5 to 10 percent smaller for binocular viewing than for monocular viewing. Campbell and Green (1965), however, found that with sinusoidal contrast threshold targets the contrast required with binocular viewing is about 42% lower with binocular viewing than with monocular viewing (Figure 5). Thus the binocular/monocular contrast sensitivity is a ratio of 1.42 which is close to the square root of 2 (1.414). They explain their result by assuming that the outputs from the two eyes contain uncorrelated noise components. Because the standard error of the sum of n independent measurements of a random or noise process decreases as $\sqrt{n}$, an observer using two eyes can obtain two measurements which thus permit a $\sqrt{2}$ lower contrast to be detected. Extrapolating these functions out to cutoff (that is, where they become high or unity contrast targets) yields a 7% decrease in the minimum angle resolvable for binocular viewing which corresponds well with the high contrast findings mentioned earlier.

III. EFFECT OF TARGET SIZE UPON PERCEIVED VELOCITY

A number of investigators have shown that when velocity is held constant, small targets are perceived as moving faster than large targets. Dr. Behar (1978) in our laboratory showed that this effect also exists under minimal conditions, i.e., when a single target is moved over a homogeneous background. In his study, he used a magnitude estimation procedure in which he presented targets of from 7.3 minutes of arc to 57.2 minutes of arc at velocities of 10, 25.5, 40, 54, and 87 degrees per second. Figure 6 shows the perceived velocity as a function of size averaged over the five velocities. Figure 7 shows the perceived velocity as a function of size for each of the five velocities. It is seen that there is an interaction such that the effect is greater for the higher velocities than for the lower velocities.

IV. MULTIPLE IMAGING PRODUCED BY SACCADIC EYE MOVEMENTS

Displays are normally refreshed at rates above the critical flicker frequency. With fast-transient technologies, however, refreshing at rates above this static (eyes fixed) fusion frequency is often not sufficient to eliminate the multiple imaging and "jumpiness" which occurs when the eyes move to scan the display. That is, when the eyes move, each successive field is imaged at a different place on the retina and the amount of non-overlap is determined by the refresh rate and the velocity of the eye movement. (The amount of non-overlap is the critical factor since the continuously visible scenes viewed in everyday life are also imaged at different places when the eyes move but, since they are overlapping, do not present these problems.)

Figure 8 shows the maximum velocity achieved for various sizes of eye movements (Westheimer, 1954). If we have, for example, a 10 minutes of arc stroke width and a 15 degree eye movement (this is about the maximum size of eye movement that occurs without a concurrent head movement) which achieves a maximum velocity of approximately 425°/sec., then a refresh rate of 2,318 instantaneously presented fields per second would give an image separation of one minute of arc. When a head movement occurs, its velocity would have to be added to that of the eye movement. These calculations are intended only to present an upper limit to the potential problem; the actual rates required would depend upon: 1) the duty cycle of the fields, (2) the manner in which the fields are "painted" on the screen, (3) the luminance of the display (the eye's temporal resolving power increases with increasing luminance), and (4) the amount of non-overlap actually required to produce the effects.

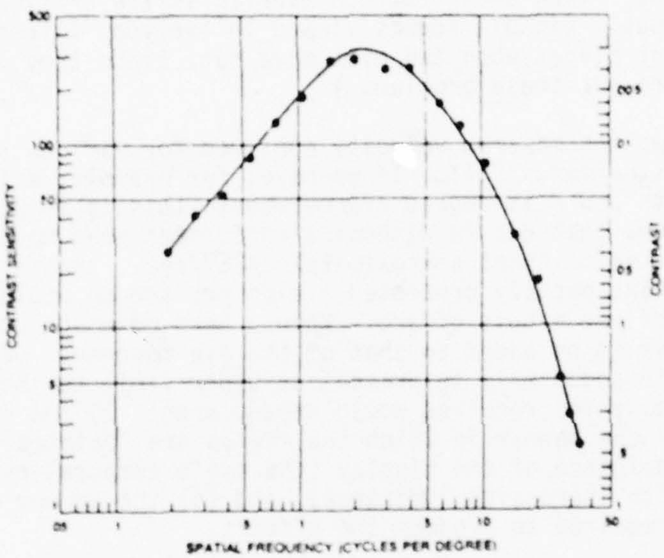


Figure 1. (From Campbell and Maffei, 1974)

CONTRAST SENSITIVITY OF A HUMAN SUBJECT is plotted as function of spatial frequency. The scales are logarithmic. Very high contrast is given a value of 1, and contrast sensitivity is the reciprocal of contrast. The human visual system is more sensitive to contrast with sine-wave gratings that have spatial frequencies of about two or three cycles per degree. Contrast sensitivity drops off at higher and lower spatial frequencies. Data were obtained by asking the subject to indicate when a particular grating could just be seen.

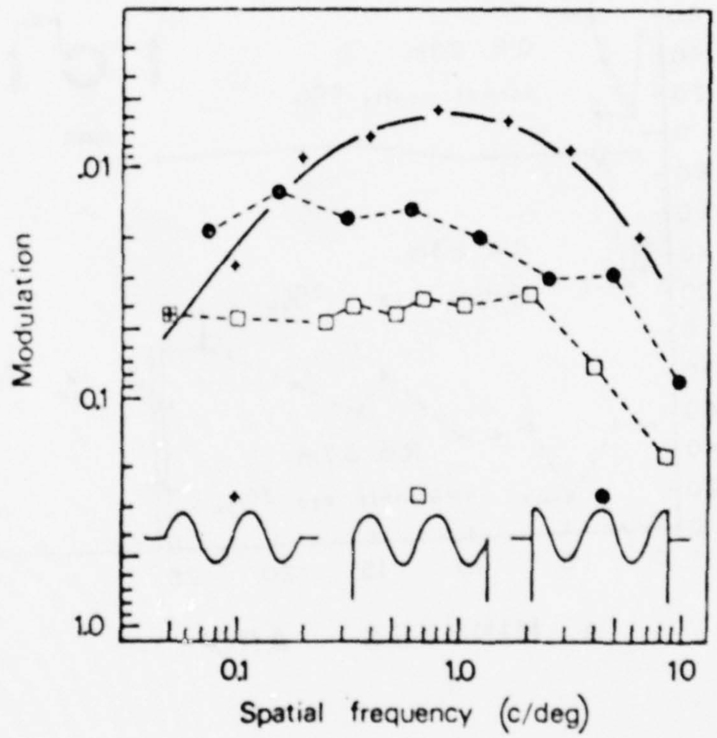


Figure 2. (From Estevex and Cavonius, 1976)

Modulation sensitivity measured with gratings that contained two periods, presented on a uniform surround (+), dark surround (□), or uniform surround, marked off from the grating by thin dark lines (●). These luminance profiles are shown schedmatically at the bottom of the figure.

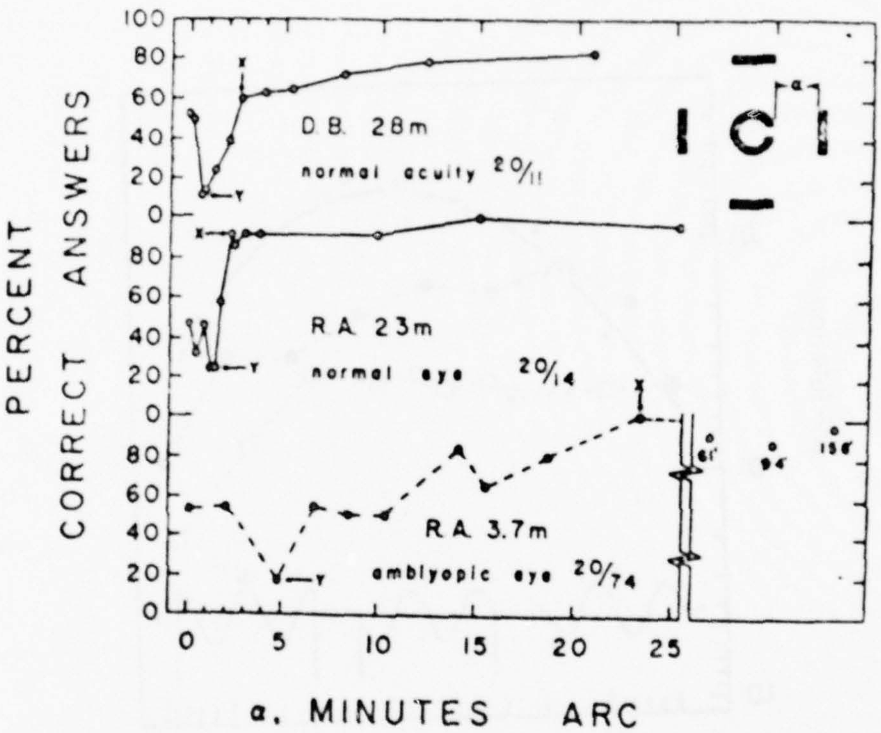


Figure 3. (From Flom, Weymouth, and Kahneman, 1963)

For a 22-mm diam Landolt C placed at the viewing distances indicated, the percent of correct answers are plotted as a function of the angular separation, α, of 4 surrounding bars for one amblyopic (broken line) and two normal eyes (solid line). Each circle represents 144 presentations for subject D.B. and about 50 for R.A. Percentages have been adjusted for 1 chance in 4 of guessing correctly. The 20-ft Snellen notation corresponding to the "interaction-free" situation (no bars) is indicated for each eye. The maximum bar separation affording interaction is specified by Point x, the bar separation producing greatest interaction is designated as Point y.

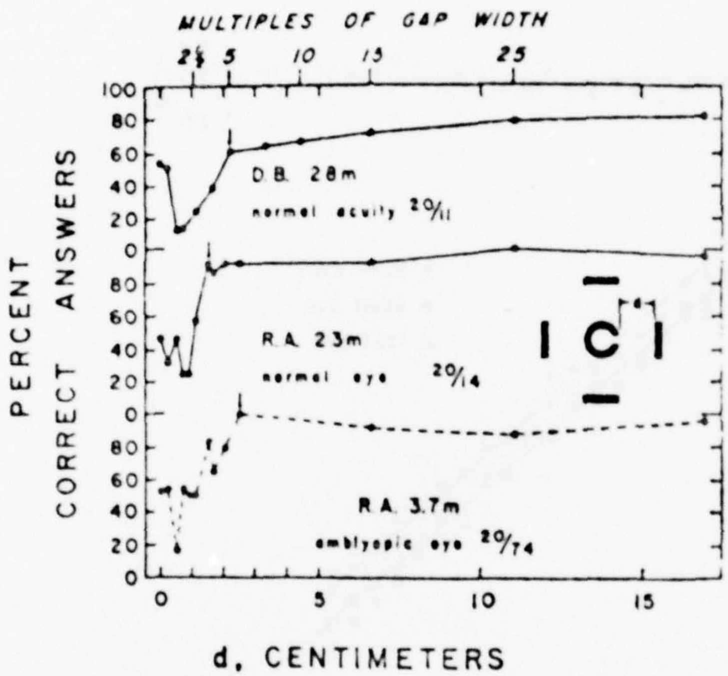


Figure 4. (From Flom, Weymouth, and Kahneman, 1963)

The probability of seeing data of Fig. 3 plotted as a function of the linear separation d between C and bars. Unlike Fig. 3, the viewing distance is disregarded in this plot and the bar separation are thus represented as multiples of the gap width. The arrow specifies the maximum bar separation affording interaction. The similarity between the curves for the amblyopic and normal eyes is notable in this plot.

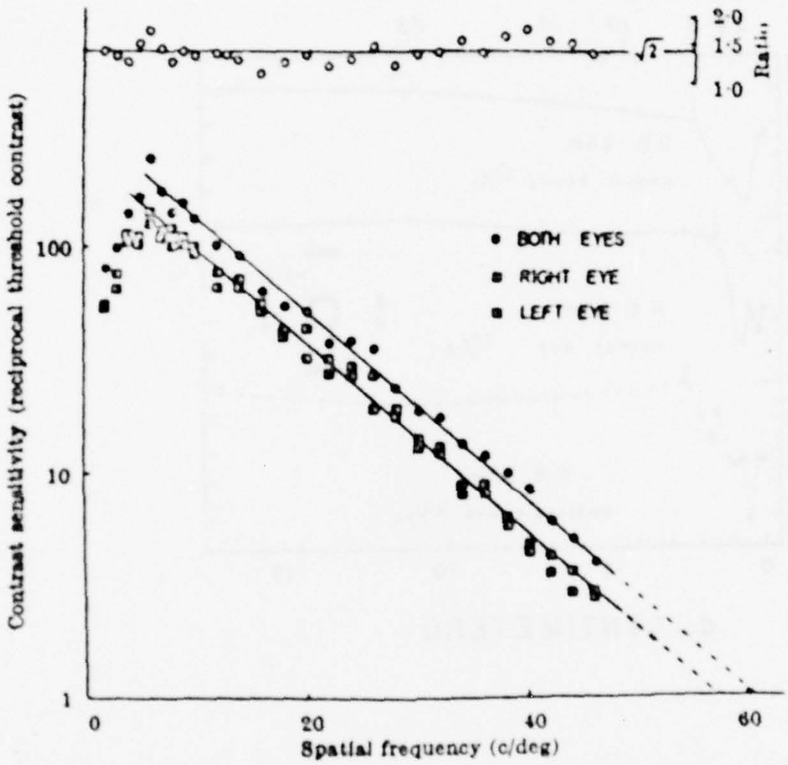


Figure 5. (From Campbell and Green, 1965)

The results from D. G. G. are plotted as contrast sensitivity on a log scale. Contrast sensitivity is defined as the reciprocal of the contrast at threshold. Contrast sensitivity = [max - [min. Spatial frequency in c/deg of visual angle is plotted on a linear scale. Each point is an average of two conservations. The two straight lines are placed at a ratio of $\sqrt{2}$ apart in contrast and fitted to the results by eye. The interrupted lines are extrapolations to unit sensitivity (100 per cent contrast). In the upper portion of the figure the open circles represent the ratio, plotted on log scale, of binocular/mean-monocular sensitivity at each spatial frequency. The straight horizontal line corresponds to a ratio of $\sqrt{2}$.

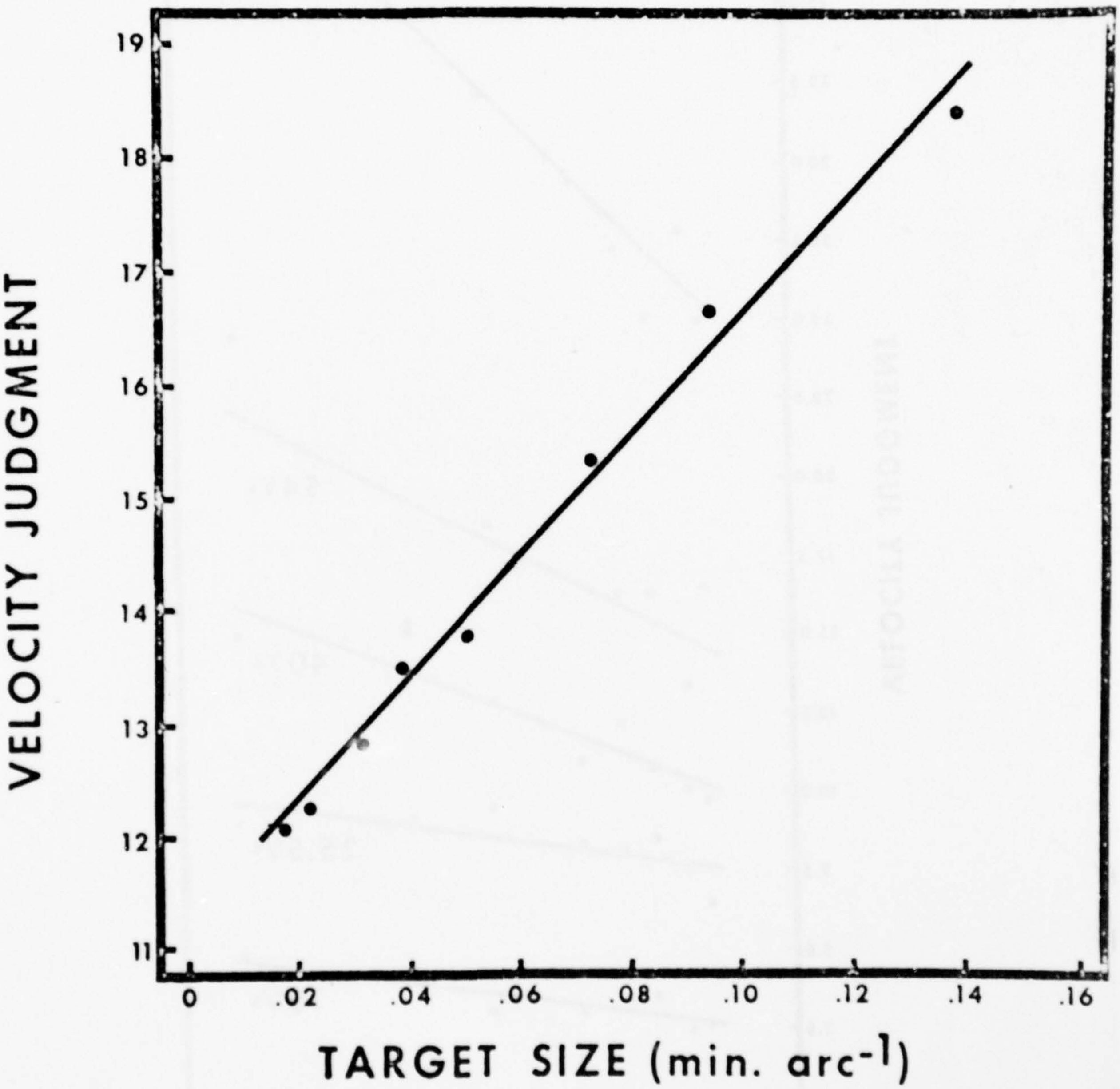


Figure 6. Velocity judgments as a function of target size averaged over all velocities (From Behar, 1978).

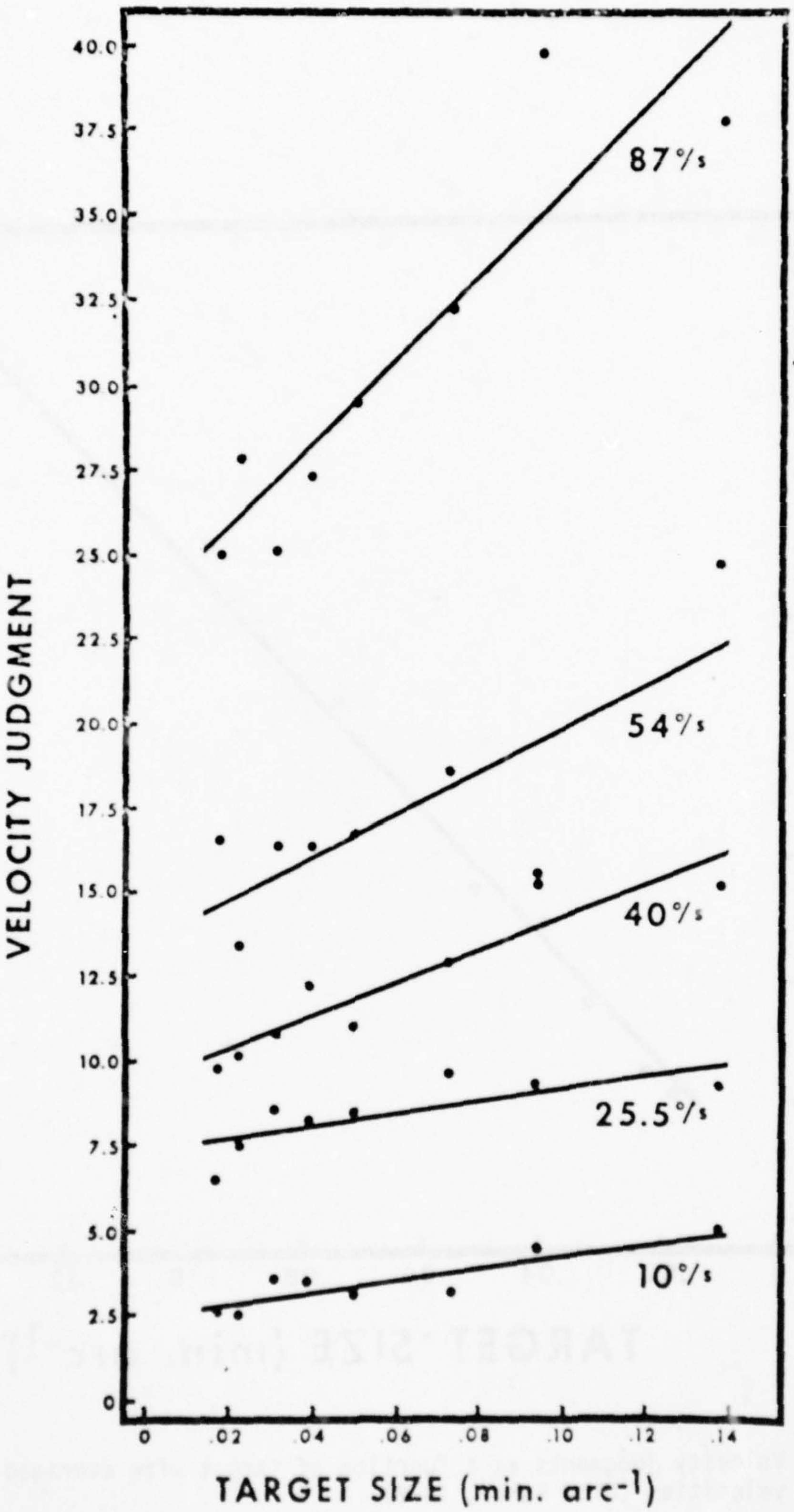


Figure 7. Velocity judgments as a function of target size for each of the five velocities (From Behar, 1978).

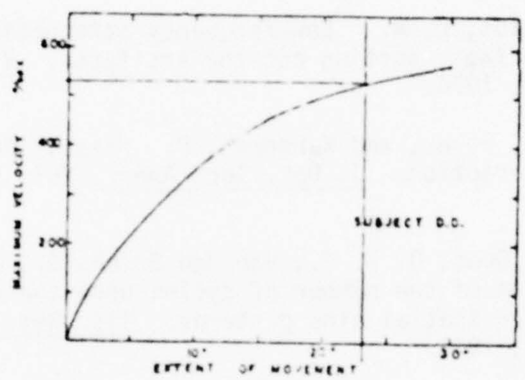


Figure 8. (From Westheimer, 1954)

Relation between maximum velocity and extent of saccadic eye movements.

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THE EFFECTS OF GLARE ON DISPLAY IMAGE LUMINANCE REQUIREMENTS

Keith T. Burnette

Bunker Ramo Corporation, Suite 302, 4130 Linden Avenue
Dayton, OHio 45432 - Phone: 513-254-1793

Sponsored by Air Force Flight Dynamics Laboratory, Crew
Systems Development Branch AFFDL/FGR under
Contract F33615-78C-3614

Introduction

The purpose of this paper is to outline some preliminary results of an approximately ten year effort aimed at analyzing and correlating human luminance requirements data. The data analyzed was acquired largely through searches of the display and visual research literature. The analysis was restricted to studies treating color normal subjects with 20/20 or better static visual acuity. The goal of the analysis was to first establish a basic set of human luminance requirements valid for known: high image quality, low image complexity display imagery when viewed under ideal environmental illumination conditions. This was accomplished and an empirical equation which describes the ideal human luminance requirements was developed. The second part of the analysis goal was to develop techniques for describing the changes in the luminance requirements made necessary when either the display or the viewing conditions are no longer ideal. The present paper is restricted to a description of how display image legibility is influenced by the presence of glare inducing illumination levels within the observer's field of view. An empirically based theoretical model for predicting the increase in the ideal display image luminance requirements when discrete and/or distributed glare sources are present is proposed.

Basis and Procedure for Data Analysis

The data analysis approach adopted here assumes that reported experimental results are valid and then identifies the commonality, differences and the sources of apparently conflicting study results. To do this involves: (1) initially becoming familiar with the available visual research data base,[1,2] (2) identifying significant variables and their interrelationships,[3,4] (3) converting the identified variables into basis

sets of mutually exclusive variables[5] and (4) establishing quantitative relationships between these variables.

Light, entering the eyes, contains all of the information the human is capable of sensing visually and therefore serves as the source of the external independent variables upon which both human visual perception capabilities and display image legibility requirements can be characterized. The luminance functional

(1) $L(r,\theta,\phi,\lambda,\psi,t)$

serves as a theoretical construct which completely describes the sensed visual scene and uniquely determines human visual performance when the full range of each of the independent variables it depends upon are specified. These variable dependences are: location within the observer's field of view (r,θ,ϕ), wavelength, λ, phase, ψ, and time, t. In the present analysis visual perception performance will be analyzed in terms of the effect of the luminance functional spatial variables within the observer's field of view. The analysis is further constrained by considering only test data which is of high image quality and low image complexity.

Luminance Requirement Relationships

Preliminary investigations of variable interrelationships resulted in emitted luminance, ΔL, (i.e. the difference between measured symbol and background luminances) background luminance, L_D, and the critical detail dimension, α_c, of an image being identified as variables most critical to a basic characterization of human image luminance requirements. The goal of the present analysis was to determine how the emitted luminance, ΔL, must be changed to maintain a fixed level of performance as internal and external cockpit surround luminance variables, L_p and L_U respectively, are changed. As a reference for this analysis all other image characteristic variables were considered to have fixed optimum performance values (i.e. static or slow moving imagery, no vibration, no acceleration, etc.)

Optimum emitted versus background luminance characteristics that were adapted from the data of Jainski,[6] and which correspond to

(2) $L_U \leq 2L_D$, $L_p \leq 2L_D$ and $E_B = 0$

were selected as a baseline reference for establishing the degrading influence of non-optimum surround luminance and glare source conditions. It

was possible to empirically characterize these optimum luminance requirements characteristic in terms of the equation

$$(3) \qquad \Delta L_P = \Delta L_{PK}(\alpha_c) \left[1 + \left(\frac{L_D}{L_{DK}} \right)^m \right]$$

where

$$(4) \qquad m = 0.926, \quad L_{DK} = 1.704 \sqrt{\Delta L_{PK}(\alpha_c)}$$

The term $\Delta L_{PK}(\alpha_c)$ must be empirically determined. It is the y axis intercept of the optimized legibility luminance requirement characteristic data.

A detailed analysis of Jainski's data, for the case where a discrete glare source is present in the observer's instantaneous field of view, resulted in the following empirical equation for veiling luminance, L_v:

$$(5) \qquad L_v(\theta_B) = \frac{1.62\, E_B^{.872}\, \theta_B^{-.74}}{1 + 4.765\times10^{-5}\, \theta_B}$$

where L_v is in foot-Lamberts (fL), E_B, the glare source illuminance, is in foot-candles (fc) and, θ_B, the angle the glare source makes with the foveal line of sight, is in degrees. Veiling luminance, as used here, is a term representing the increase in the perceived background luminance in the foveal visual field when the eyes are exposed to a source of glare in the peripheral or parafoveal fields of view. The use of veiling luminance appears to have been first postulated by Holladay. The veiling luminance, L_v, is added to the measured display or scene background luminance, L_D, to produce the perceived background luminance $L_v + L_D$. Veiling luminance can therefore be accounted for in the luminance requirement equation, by writing it in the modified form

$$(6) \qquad \Delta L_P = \Delta L_{PK}(\alpha_c) \left[1 + \left(\frac{L_D + L_V}{L_{DK}} \right)^m \right], \quad m = .926$$

where L_V is given by Equation 5

A generalization of the veiling luminance model to the case where the glare source is distributed, rather than discrete, was made and was subsequently verified by numerical integration for Jainski's distributed glare

AD-A077 061 AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH F/G 17/5
DISPLAY WORKING GROUP JOINT DARCOM/NMC/AFLC/AFSC PANEL ON THE F--ETC(U)
OCT 79 W N KAMA , W L MARTIN , G G KUPERMAN
UNCLASSIFIED AMRL-TR-79-101 NL

3 OF 4
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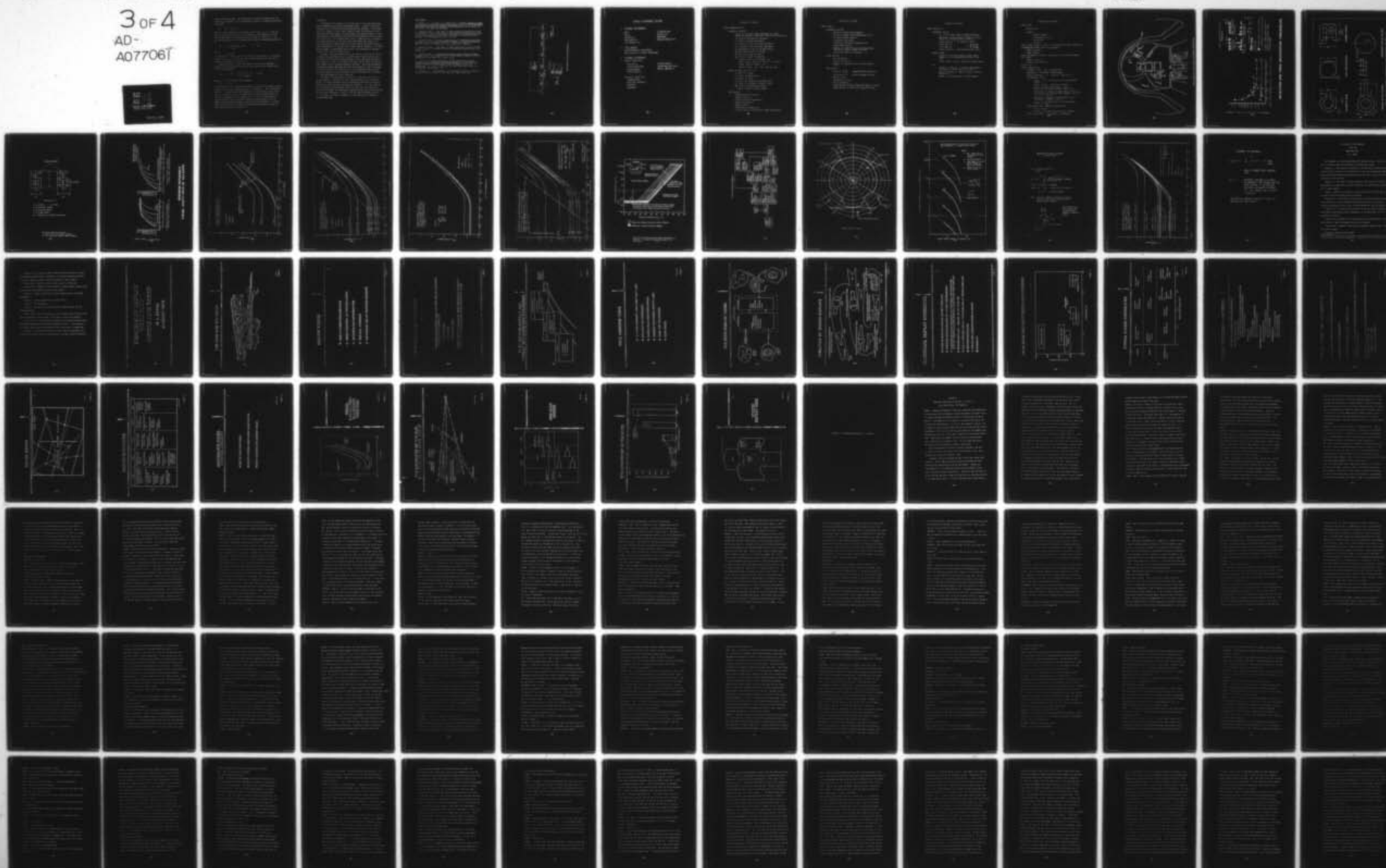

source experimental data. The generalization involves considering the illuminance E_B in Equation 5 to be a differential source of illuminance satisfying the equation

$$(7) \qquad dE_B = \frac{1}{\pi} L_B(\theta,\phi) d\Omega$$

where $d\Omega$ is the differential solid angle of the source, $L_B(\theta,\phi)$ is the luminance of the source and division by π converts L_B from candles per square foot to foot-Lamberts to make the units consistent with those of L_v. The veiling luminance due to a distributed glare source can therefore be expressed as:

$$(8) \qquad L_v = \frac{1}{\pi^k} \int_{\Omega_{FOV}} f(\theta) L_B(\theta,\phi)^k d\Omega \qquad k = .872$$

where

$$(9) \qquad d\Omega = \sin\theta d\theta d\phi$$

The integration is taken over the solid angle of the observer's instantaneous field of view, Ω_{FOV}, excluding the area of the fovea which has the display background luminance L_D incident on it.

Combining Equations 8 and 9 and expressing the angular dependence in radians rather than degrees the general form of the veiling luminance equation can be expressed as:

$$(10) \qquad L_v = \frac{.081}{\pi^{.872}} \int_0^{2\pi} \int_{\theta_F}^{\theta_L} \frac{L_B(\theta,\phi)^{.872} \theta^{-.74}}{1 + 8.9626 \theta^{3}} \sin\theta d\theta d\phi$$

where $\theta_F = 3°$ is the radius of the fovea and

$$(11) \qquad \theta_L = g(\phi)$$

In this expression $g(\phi)$ defines the perimeter of vision for the human's instantaneous field of view. Contributions to L_v for angles $\theta_L > 60°$ are generally negligible. If desired and the luminance of a discrete glare source such as the sun is known, it can be considered a part of the distributed glare and simply be integrated over using Equation 10. If not, its contribution to veiling luminance can be calculated separately using Equation 5 and then added to the distributed luminance contribution from Equation 10. In either event the total veiling luminance can be used with Equation 6 to establish the perceived luminance requirement, ΔL_p.

Conclusions

The results of this analysis are at best only a first step toward developing a comprehensive luminance requirements model. A number of the image characteristic variables held constant here are very important. The variable time, for instance, is particularly important under night adaptation conditions where external targets can be obscured by the combined effects of slow dark adaptation time constants and by the veiling luminance caused by cockpit lighting acting as a distributed glare source. Likewise color is covered by the present model only to the extent that unsaturated color symbols on a white background have been shown to be no more legible than white symbols on a white background (i.e. the purity of a symbol hue of luminance ΔL is reduced when the symbol is superimposed over a white light background of luminance L_D due to the color mixing that occurs).

Although it would be tempting to use the results of the present analysis in night vision applications such as either cockpit lighting designs to try to optimum target identification performance, or for the design and performance analysis of night vision goggles; the model has not been verified under these ranges of the illuminance/luminance variables. While the experimental illuminance/luminance magnitude data upon which Equations 5 and 10 are based did cover the night vision condition fully, and therefore should be valid, the angular weighting function dependence was derived under high illuminance (i.e. daylight adaptation level) conditions.

The analysis of the available literature for the night vision case is not yet complete. The majority of the studies reported in the literature predict $f(\theta)$ angular weighting function dependences that drop off much more rapidly with increasing angle than Equation 5 predicts. It is not clear at this time whether the differences result from the significant differences that do exist between the experimental apparatus and testing criteria employed by the various researchers, or that in fact the angular weighting function $f(\theta)$ is actually functionally dependent on the glare source illuminance/luminance magnitudes.

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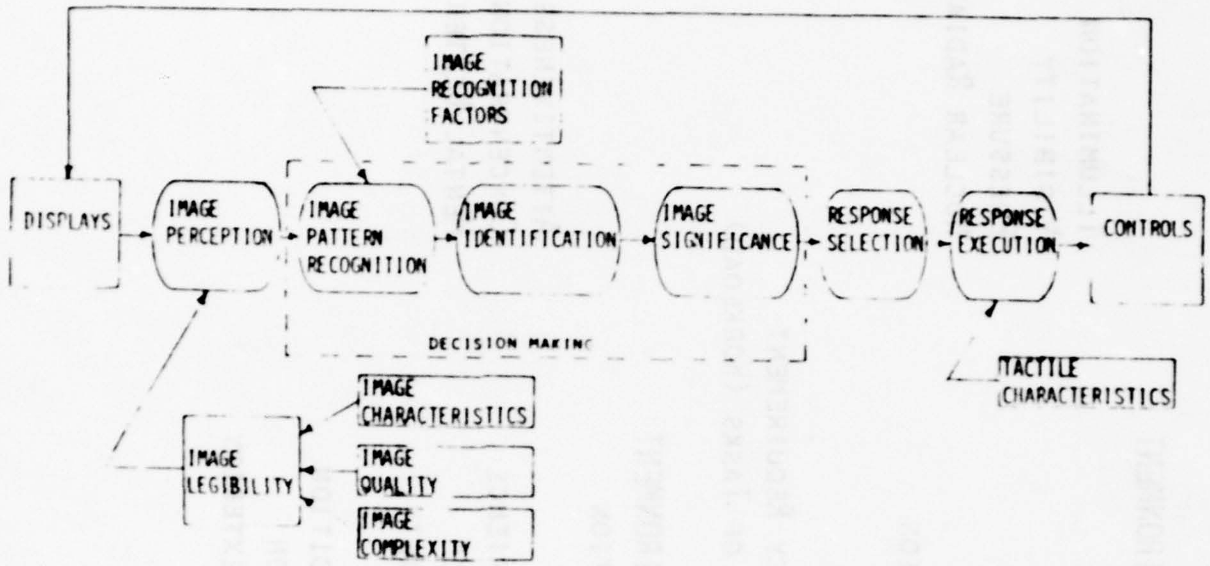
7. Holladay, L.L., "The Fundamentals of Glare and Visibility", Journal of the Optical Society of America, V12, N4, April 1926, pp 271-319.



HUMAN CONTROL-DISPLAY INFORMATION PROCESSING

INDIRECT PERFORMANCE FACTORS

1. EXTERNAL ENVIRONMENT

   HEAT
   NOISE
   VIBRATION
   ACCELERATION
   AIR COMPOSITION
   ILLUMINATION
   VISIBILITY
   PRESSURE
   NUCLEAR RADIATION

2. TASK LOADING

   SPEED/ACCURACY REQUIREMENT
   MULTIPLICITY OF TASKS (WORKLOAD)

3. INTERNAL ENVIRONMENT

   MENTAL CONDITION

   - MOTIVATION
   - PRIOR EXPERIENCE
   - PERSEVERENCE
   - STRESS-ANXIETY
   - ATTENTIVENESS
   - CONCENTRATION LEVEL
   - MENTAL DEXTERITY

   PHYSICAL CONDITION

   - COORDINATION
   - PHYSICAL DEXTERITY
   - STRENGTH
   - ENDURANCE

LEGIBILITY FACTORS

IMAGE CHARACTERISTICS

LUMINANCE FACTORS

- L_S or ΔL Display Image Luminance or Image Absolute Luminance Contrast (Perceived Luminance)
- L_D Display Background Luminance
- L_P Panel Surround Luminance
- L_I Internal-Field Surround Luminance
- L_U External-Field Surround Luminance
- L_B Luminance of Sun or Bright Objects
- θ_H Horizontal Angle of Object
- θ_V Vertical Angle of Object
- α_C Critical Detail Dimension
- Stroke Width (% of Height); 15
- Aspect Ratio (Width to Height %); 50-100
- Slant; Vertical Best; $\leq 10°$
- Viewing Angle; $\pm 30°$, $\pm 45°$ Side by Side

COLOR FACTORS (Hue, Purity)

- C_S Color of Image
- C_D Color of Background
- C_P Color or Panel
- C_I Color of Internal Surround Field
- C_U Color of External Surround Field
- C_B Color of Illuminance Source
- Color Signal to Noise Ratio

TIME FACTORS

- Image/Display Vibration
- Human Vibration
- Image/Display Acceleration
- Human Acceleration
- Image Velocity
- Information Update Rate
- Flicker Rate on Flash Rate Coded Information

LEGIBILITY FACTORS

IMAGE QUALITY

LUMINANCE FACTORS

- Relative Image Edge Gradient
- Picture Element Size-Dimensions X by Y
- Picture Element Density
- Luminance Uniformity
- Luminance Averaging Diameter/Task
- Image Registration
- Number of Comparatively Distinguishable Luminance Levels (Shades of Gray)
- Electrical/Optical Crosstalk

COLOR FACTORS

- Hue Uniformity
- Purity Uniformity
- Number of Comparatively Distinguishable Colors

TIME FACTORS

- Refresh Rate } Image/Observer Relative
- Persistence } Motion Induced Flicker
- Image Jitter
- Luminance Flicker
- Color Constancy
- Image-Motion-Induced Image Periphery Flicker
- Image Motion in Spatially Discrete Steps

LEGIBILITY FACTORS

IMAGE COMPLEXITY

LUMINANCE FACTORS

- No. of Distinguishable Images Employed
- Luminance Image Clutter (Signal to Noise Ratio or the Image Rivalry Ratio)
- Image Spacing (% of Height): 26-63
- Word Spacing ("): 60 Minimum
- Line Spacing ("): 50 Minimum
- Image Location in Observer Visual Field

COLOR FACTORS

- Number of Distinguishable Color Coded Images for the Background Colors to be Used
- Color Image Clutter (Signal to Noise Ratio)

TIME

- Number of Changes in Display Background Luminance or Color Per Unit Time
- Rate of Change of Image Clutter in Display Background
- Number of Independently Moving Images

RECOGNITION FACTORS

IMAGE SHAPE

SCENIC/VIDEO

SYMBOLIC

- Symbol Shapes
- Alphanumeric Font
- Scale Font
- Graphics

IMAGE COLOR (Single, Multi, True and False Color Rendition)

INFORMATION FORMAT (Multiple Imagery)

IMAGE PLACEMENT

IMAGE DYNAMICS

IMAGE INFORMATION CONTENT (Expressed in Picture Elements Per Image)

TARGET DETECTION

TARGET IDENTIFICATION

DISPLAY SIZE

IMAGE SIGNIFICANCE

ALPHABETS USED - NO. OF CHARACTERS

VOCABULARY - COMPOUND SYMBOLS/WORDS

PRIOR EXPERIENCE (i.e., Realism, Familiarity)

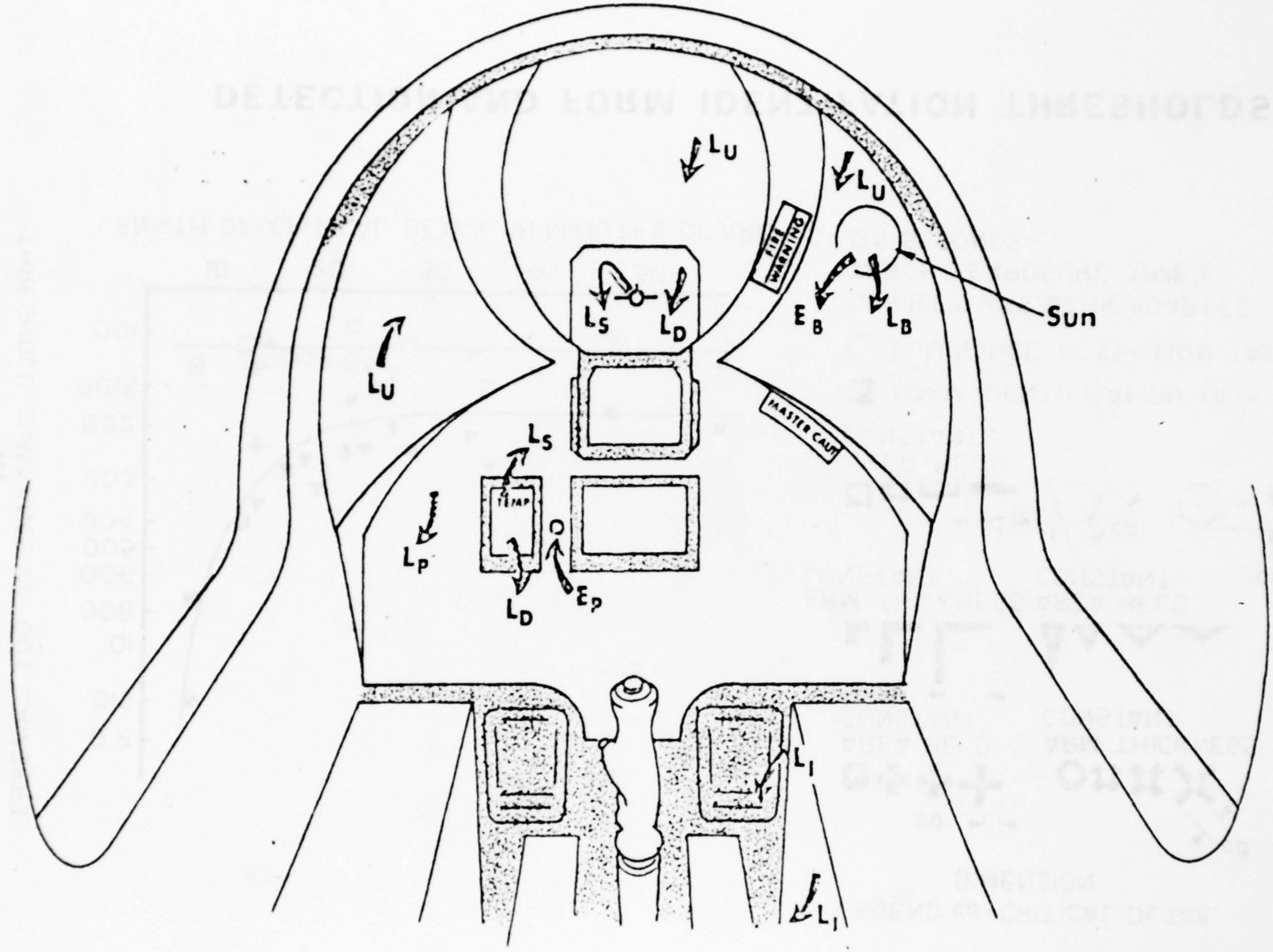
INFORMATION CODING

- Shape - No. of Absolutely Distinguishable Shapes
- Image Texture - Hatching, Shading
- Colors (Symbol/Background) - No. of Absolutely Distinguishable Colors; 5-8
- Flash Rate - Number of Absolutely Distinguishable Flash Frequencies; Range: .25-12HZ 1/3, 1. 4HZ optimum
- Luminance - Number of Absolutely Distinguishable Luminance Levels; 2
- Size - No. of Absolutely Distinguishable Sizes of imagery

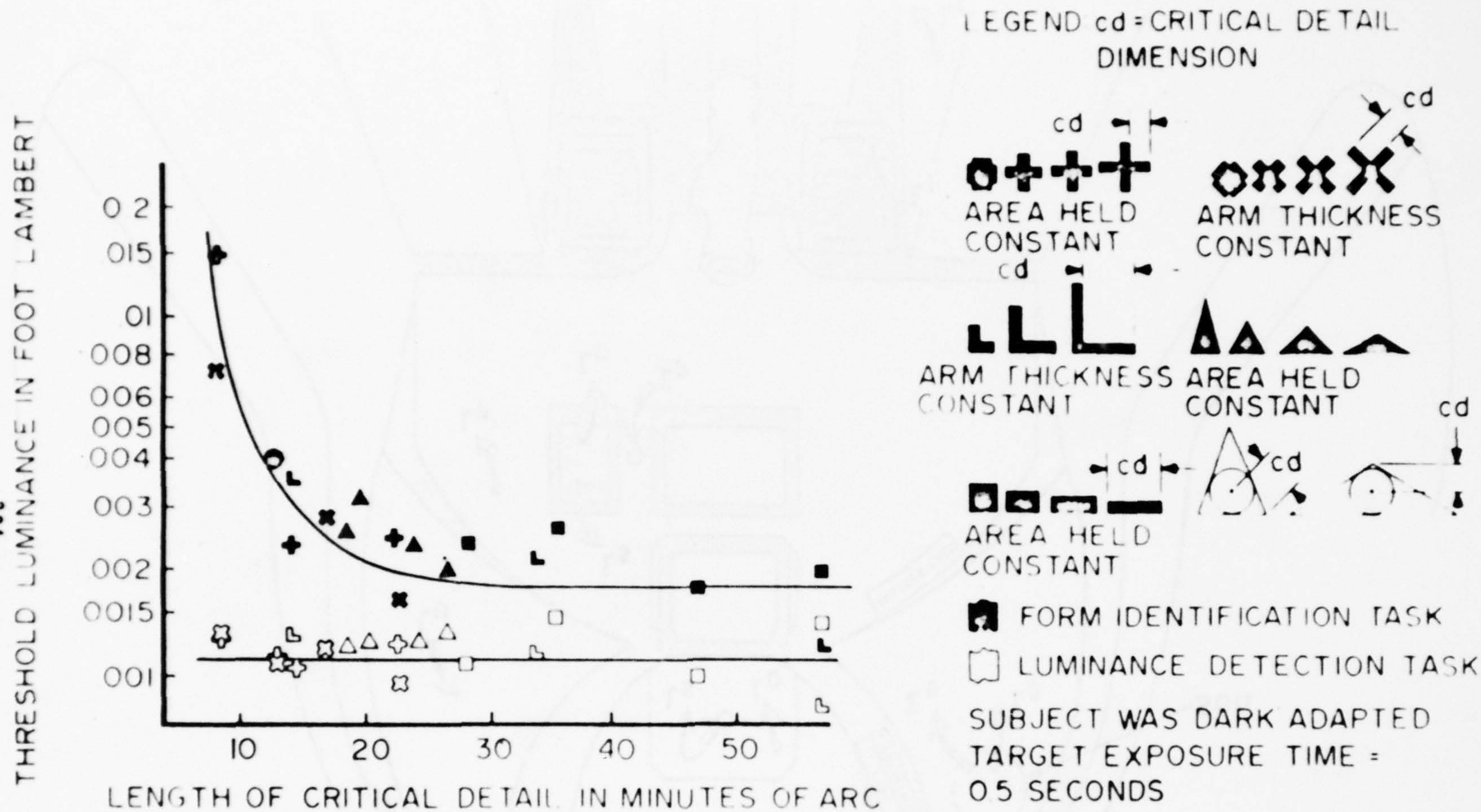
IMAGE/REAL WORLD DYNAMIC RELATIONSHIPS

- Motion Scaling
- Observer Perspective/Scaling of Imagery

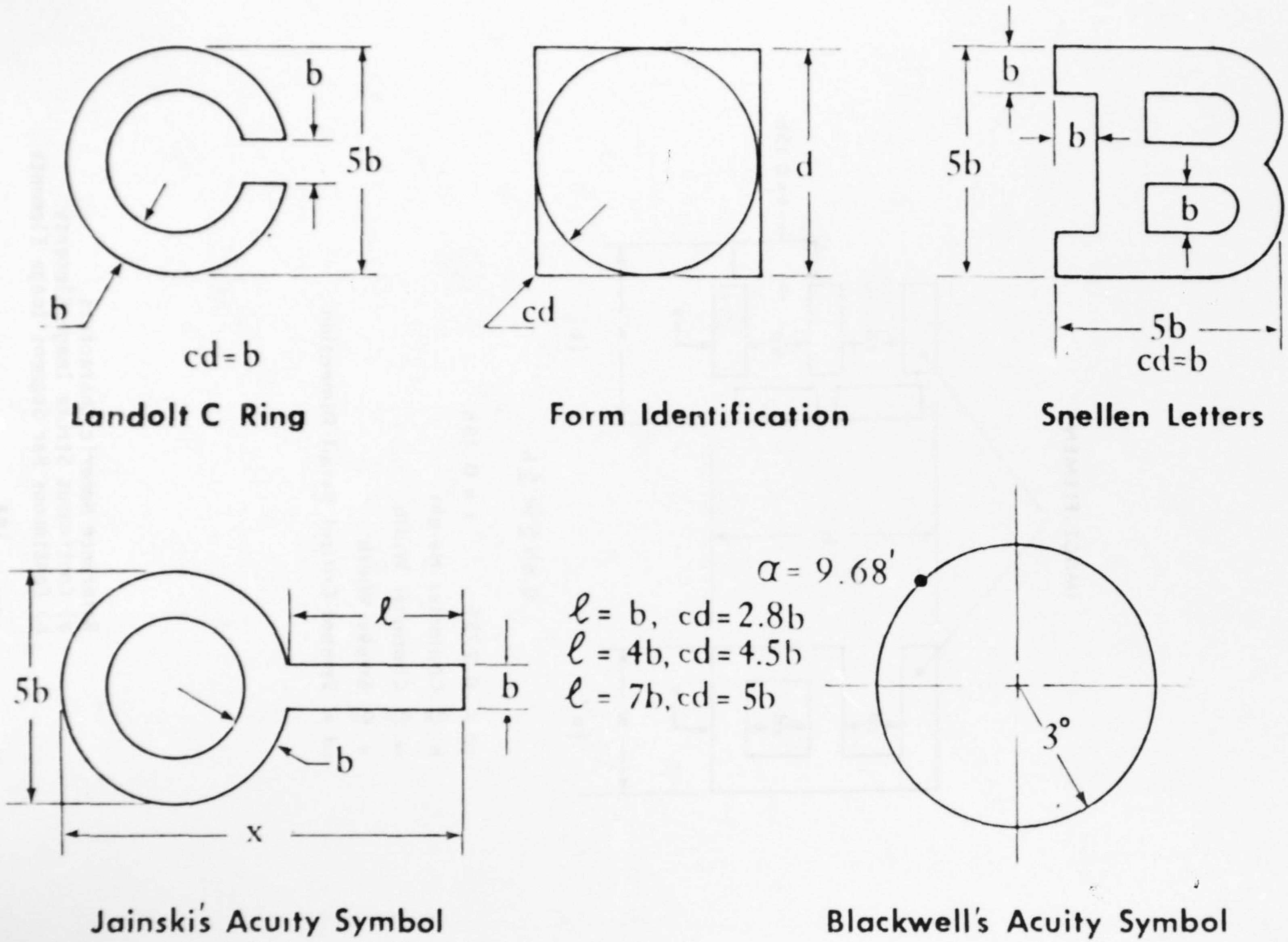
IMAGE ORIENTATION WITH RESPECT TO OBSERVER



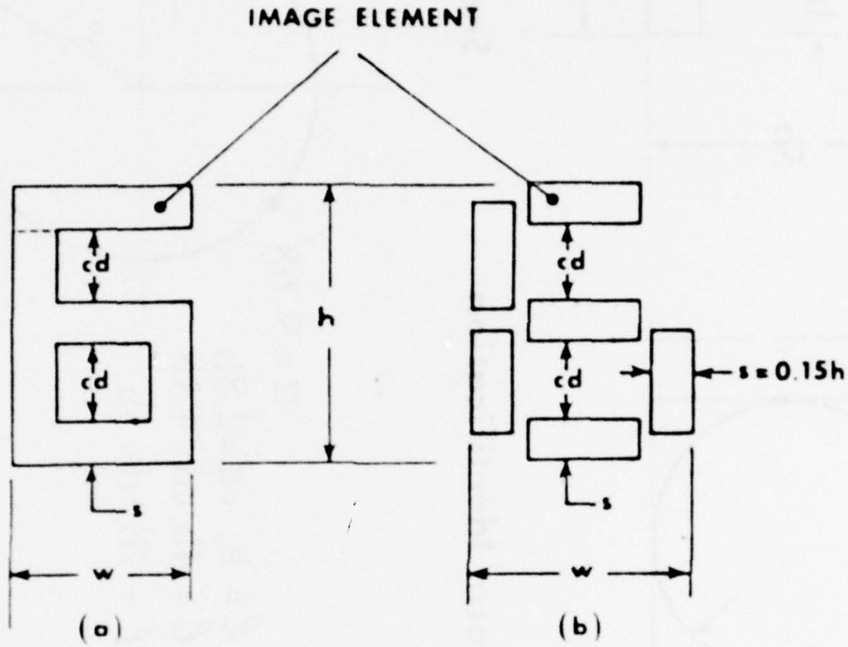
Crewstation Luminous Variable Geometry



DETECTION AND FORM IDENTIFATION THRESHOLDS



VISUAL ACUITY SYMBOL GEOMETR'IES AND CRITICAL DETAIL "cd"



$0.6h \leq w \leq h$

cd = 0.275h s = 0.15h

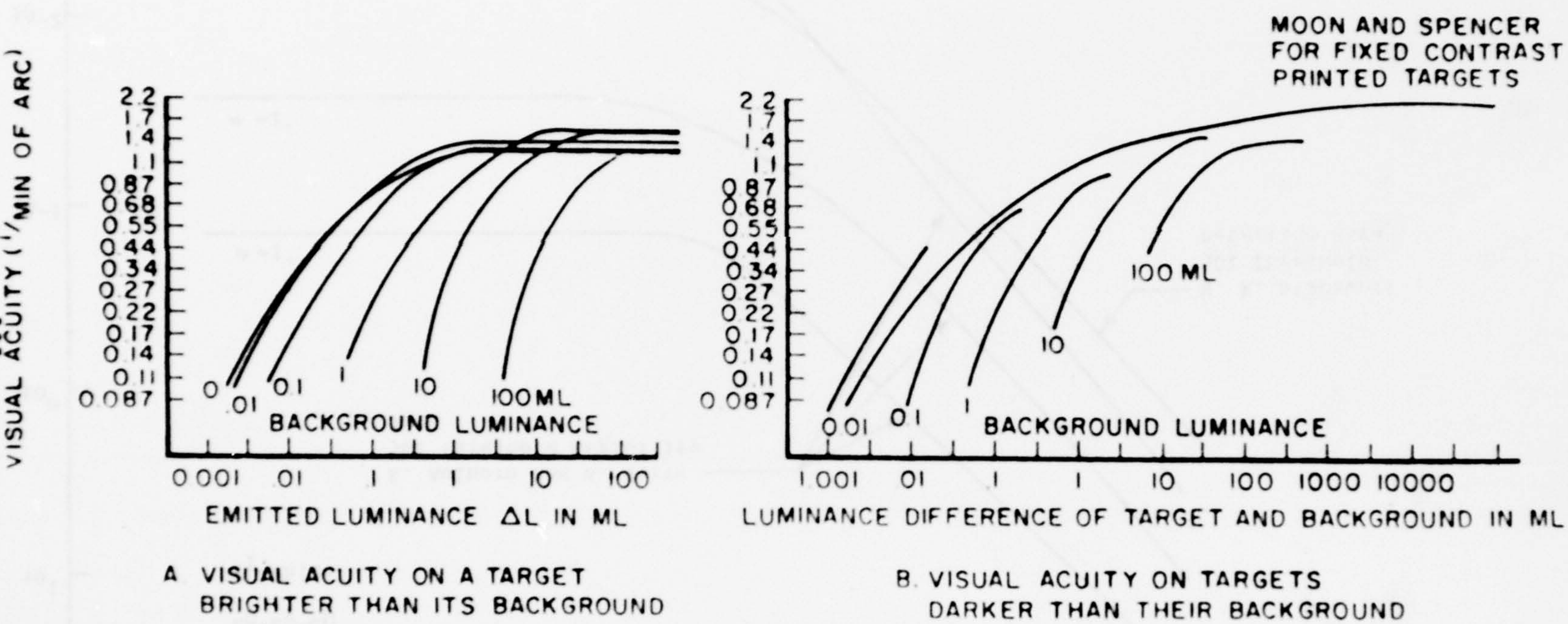
h $\triangleq$ Character Height

w $\triangleq$ Character Width

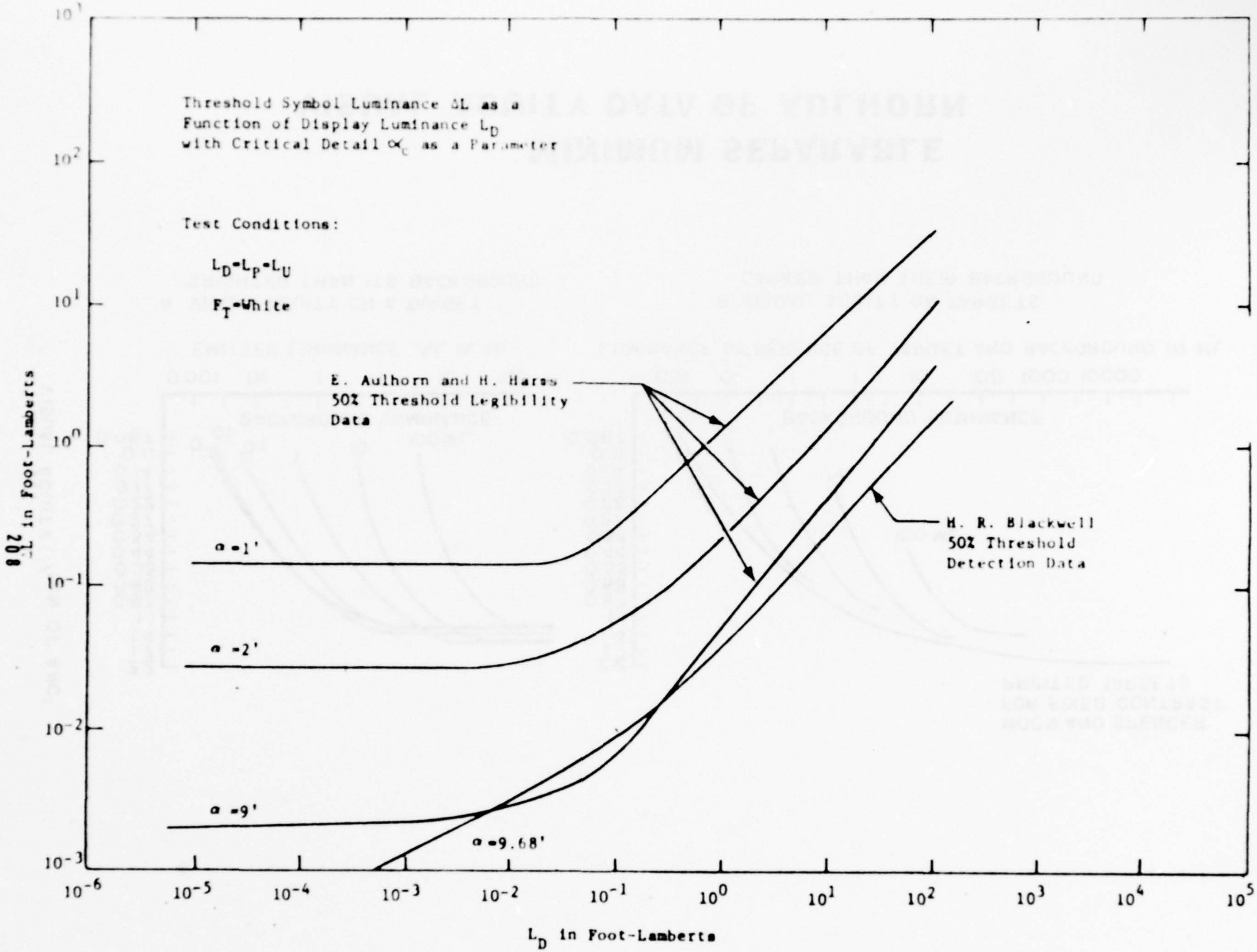
s $\triangleq$ Stroke Width

cd = Symbol Critical Detail Dimension

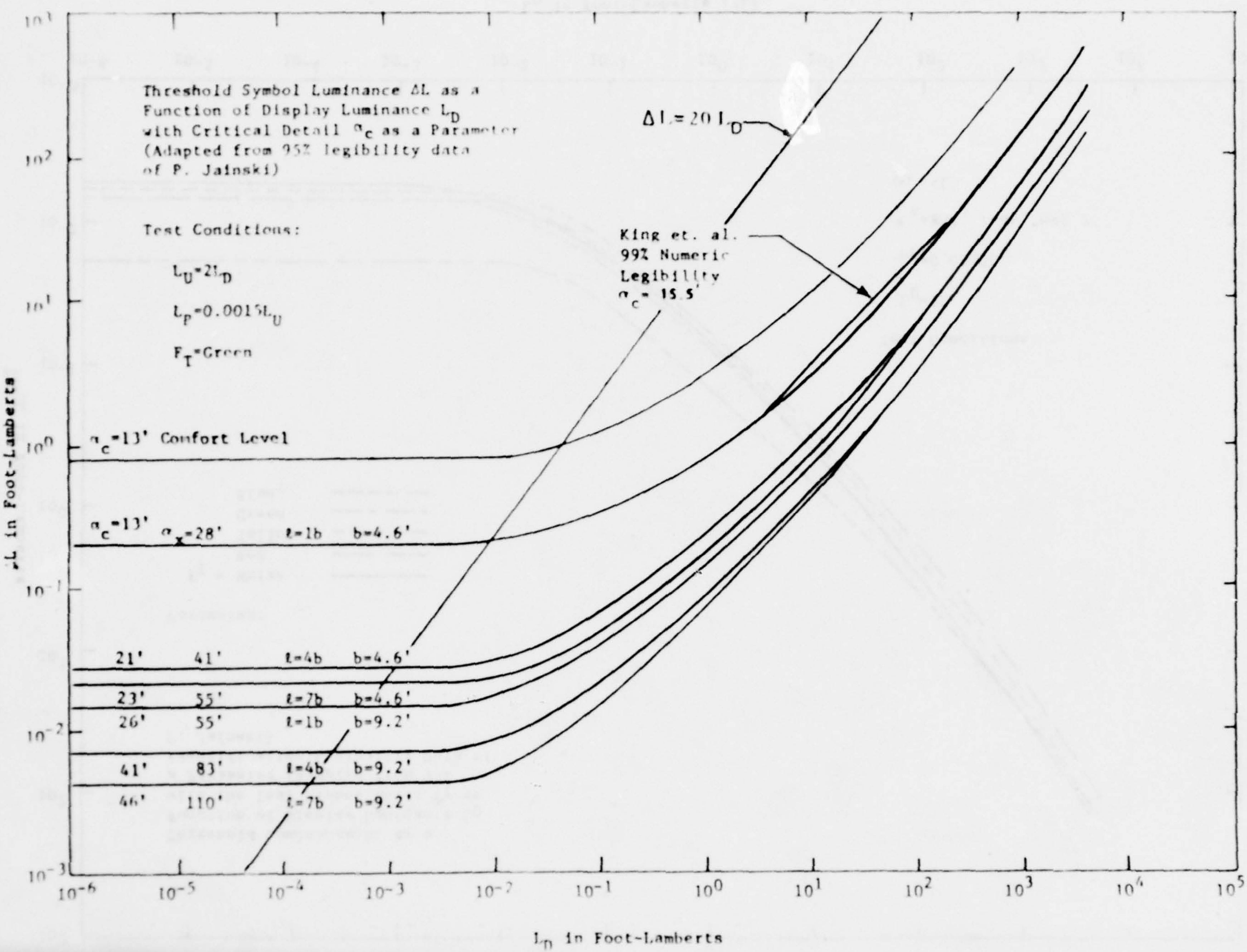
Reference Numeric Characters
a) Continuous Stroke Image Elements
b) Continuous Bar Segment Image Elements

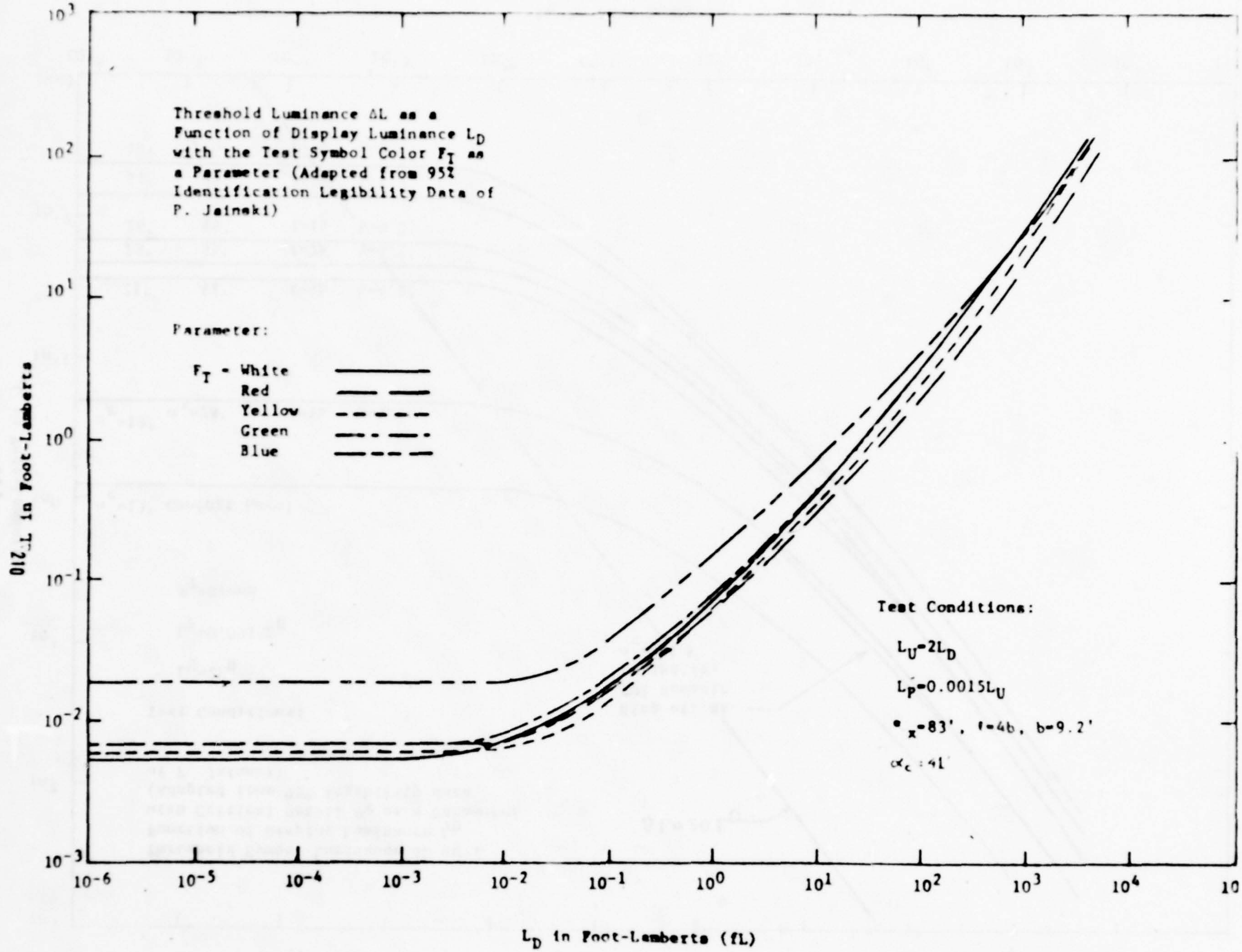


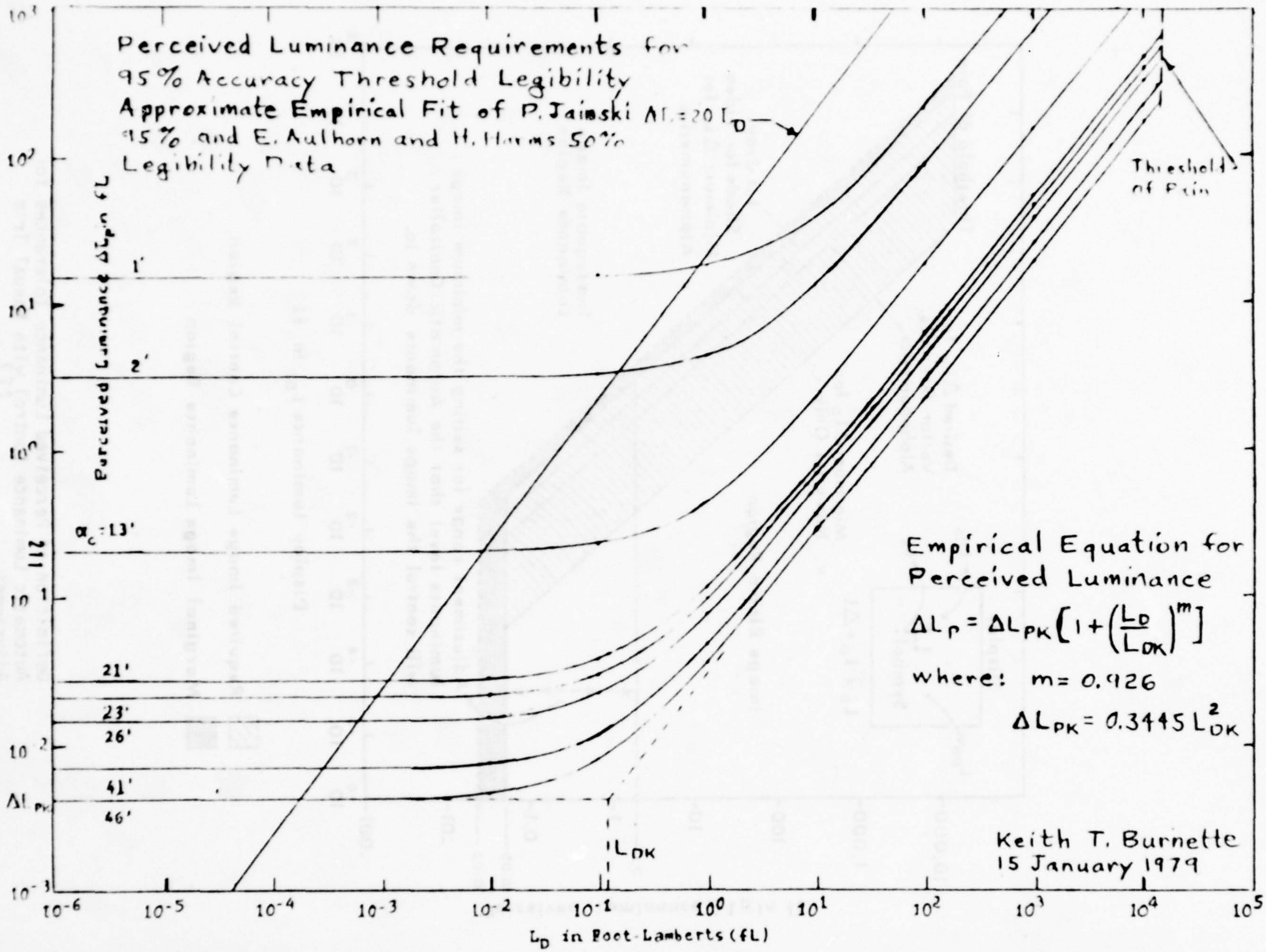
MINIMUM SEPARABLE
VISUAL ACUITY DATA OF AULHORN



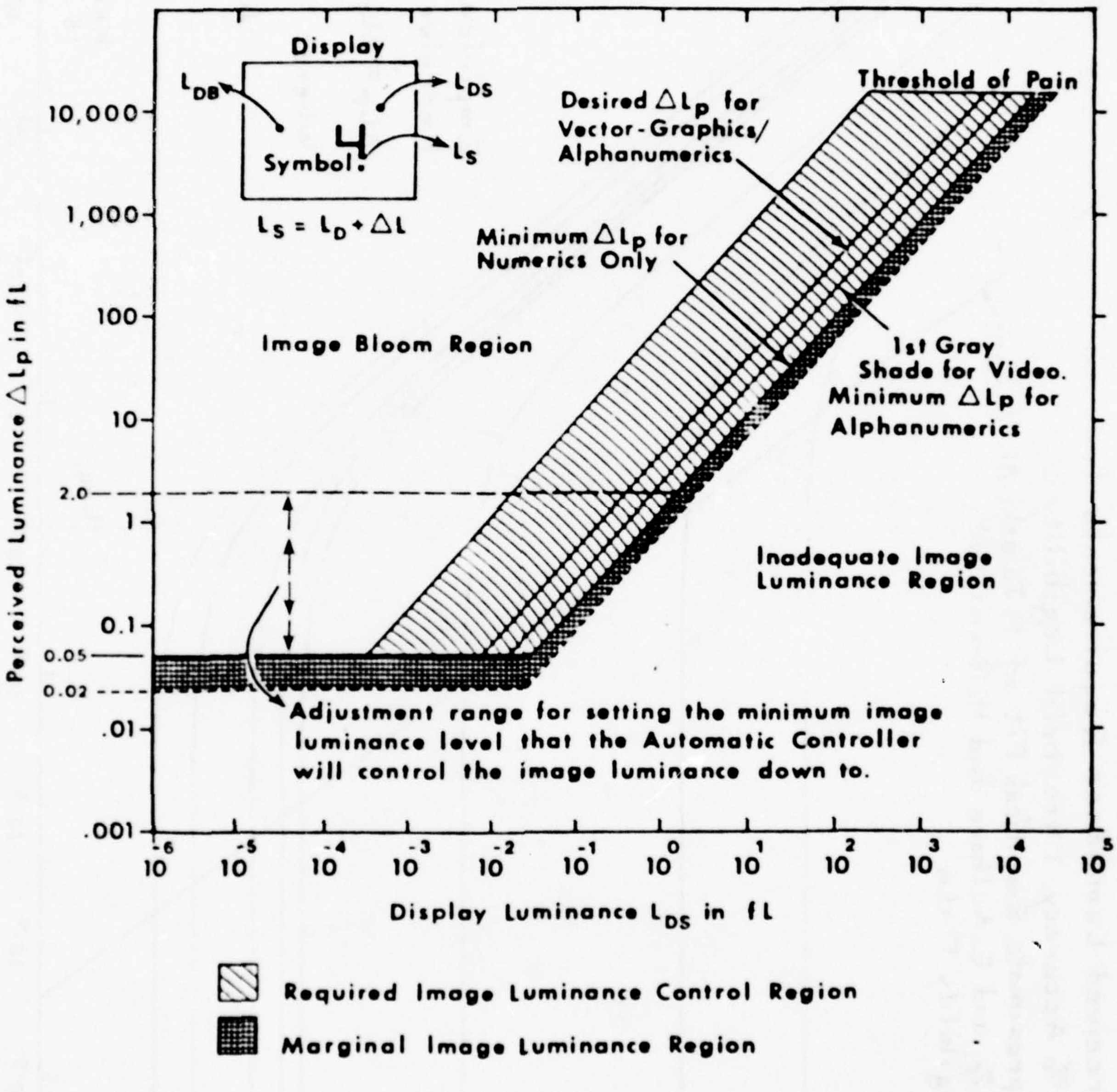
Threshold Symbol Luminance ΔL as a
Function of Display Luminance L_D
with Critical Detail α_c as a Parameter
Test Conditions:
$L_D = L_P = L_U$
F_T = White
E. Aulhorn and H. Harms
50% Threshold Legibility
Data
H. R. Blackwell
50% Threshold Detection Data
α = 1'
α = 2'
α = 9'
α = 9.68'
10^1
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
10^4
10^5
L_D in Foot-Lamberts
ΔL in Foot-Lamberts


Threshold Symbol Luminance ΔL as a Function of Display Luminance L_D with Critical Detail α_c as a Parameter (Adapted from 95% legibility data of P. Jainski)
Test Conditions:
$L_U = 2L_D$
$L_P = 0.0015 L_U$
F_T = Green
$\Delta L = 20 L_D$
King et. al. 99% Numeric Legibility $\alpha_c = 15.5'$
$\alpha_c = 13'$ Comfort Level
$\alpha_c = 13'$ $\alpha_x = 28'$ $\ell = 1b$ $b = 4.6'$
21' 41' $\ell = 4b$ $b = 4.6'$
23' 55' $\ell = 7b$ $b = 4.6'$
26' 55' $\ell = 1b$ $b = 9.2'$
41' 83' $\ell = 4b$ $b = 9.2'$
46' 110' $\ell = 7b$ $b = 9.2'$
ΔL in Foot-Lamberts
L_D in Foot-Lamberts


Threshold Luminance ΔL as a Function of Display Luminance L_D with the Test Symbol Color F_T as a Parameter (Adapted from 95% Identification Legibility Data of P. Jainski)
Parameter:
F_T - White
Red
Yellow
Green
Blue
Test Conditions:
$L_U=2L_D$
$L_P=0.0015L_U$
$\theta_x=83'$, f=4b, b=9.2'
$\alpha_c=41'$
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10
L_D in Foot-Lamberts (fL)
10^{3} 10^{2} 10^{1} 10^{0} 10^{-1} 10^{-2} 10^{-3}
ΔL in Foot-Lamberts

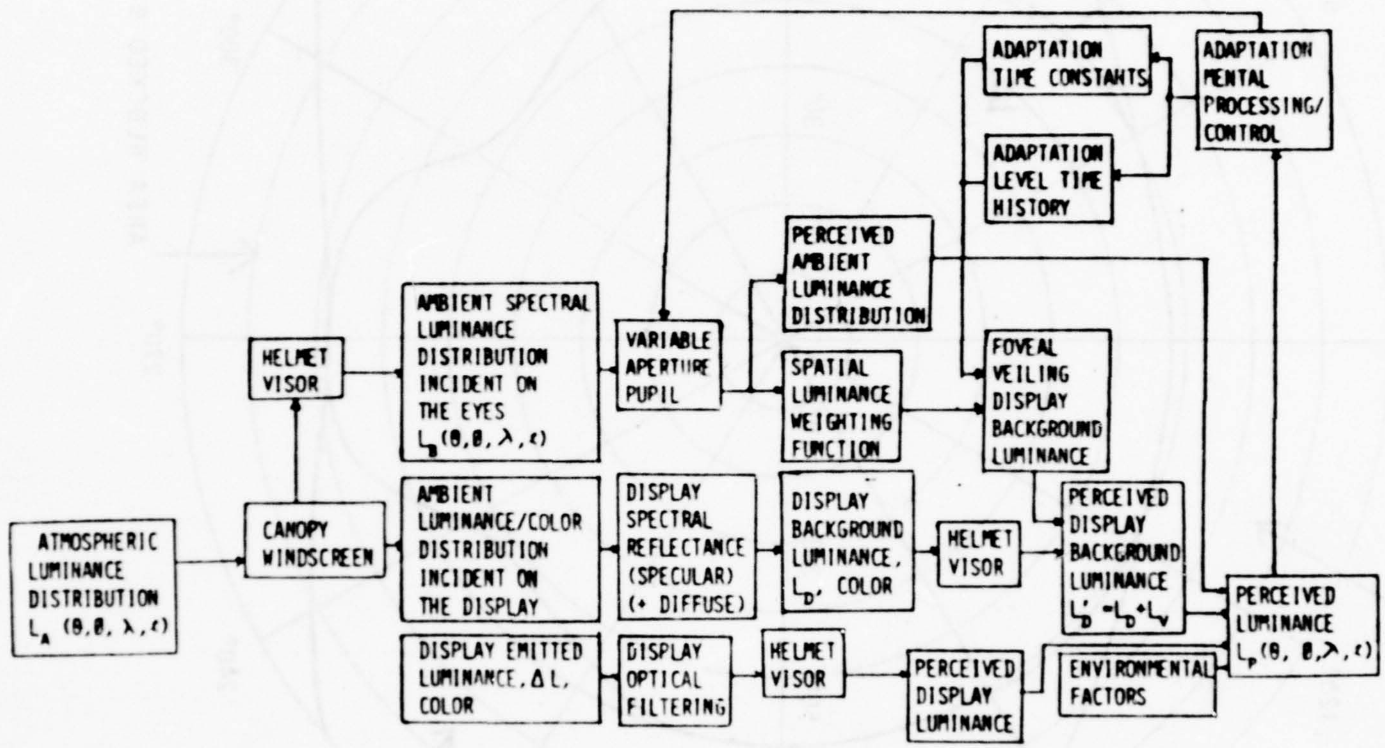


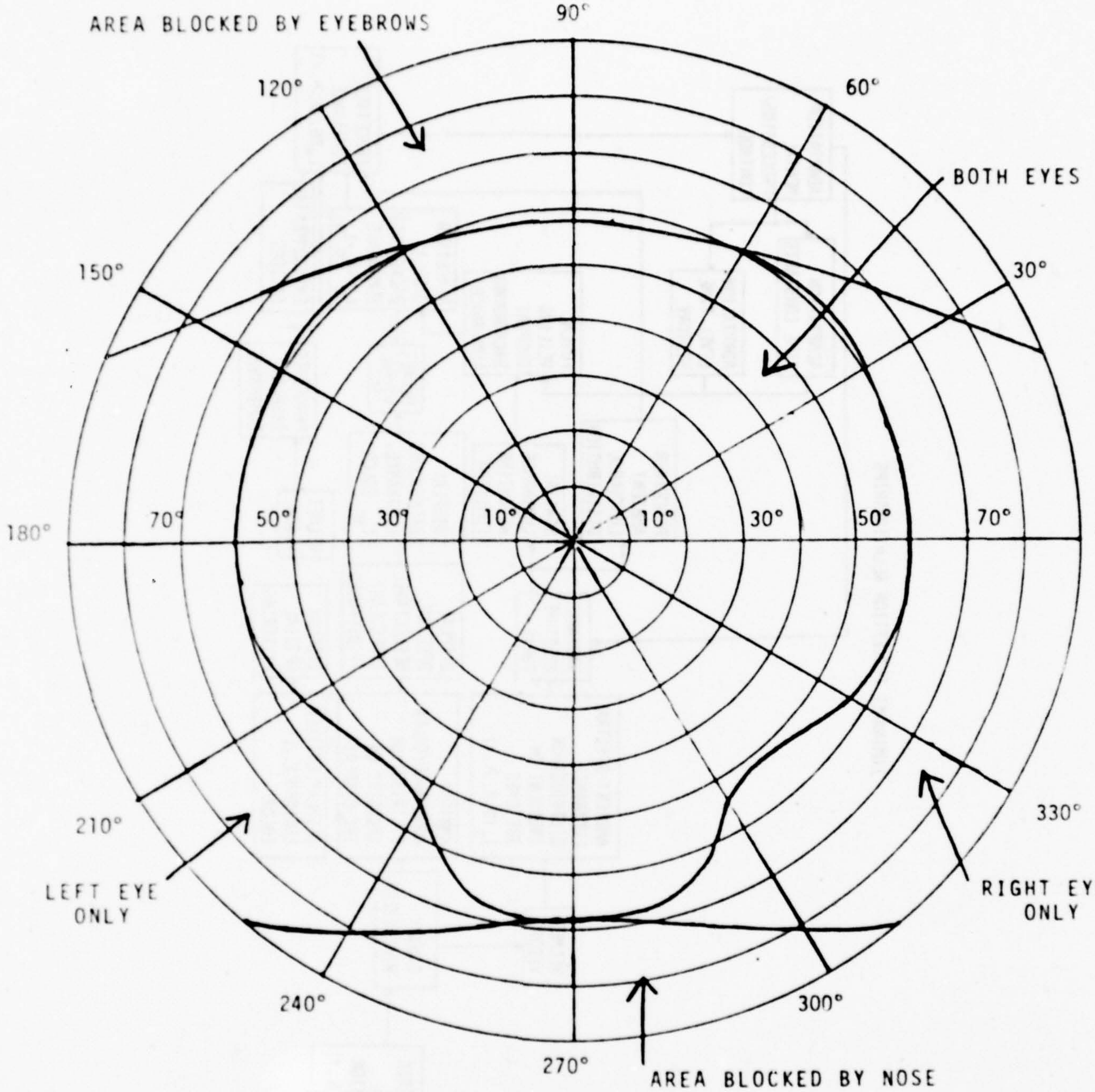
Perceived Luminance Requirements for
95% Accuracy Threshold Legibility
Approximate Empirical Fit of P. Jainski
95% and E. Aulhorn and H. Harms 50%
Legibility Data
$\Delta L = 20 L_D$
Threshold of Pain
Perceived Luminance ΔL_p in fL
1'
2'
$\alpha_c = 13'$
21'
23'
26'
41'
46'
ΔL_{PK}
L_{DK}
Empirical Equation for
Perceived Luminance
$\Delta L_p = \Delta L_{PK}\left[1+\left(\frac{L_D}{L_{DK}}\right)^m\right]$
where: $m = 0.926$
$\Delta L_{PK} = 0.3445\, L_{DK}^2$
Keith T. Burnette
15 January 1979
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3} 10^{4} 10^{5}
L_D in Foot-Lamberts (fL)
10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}



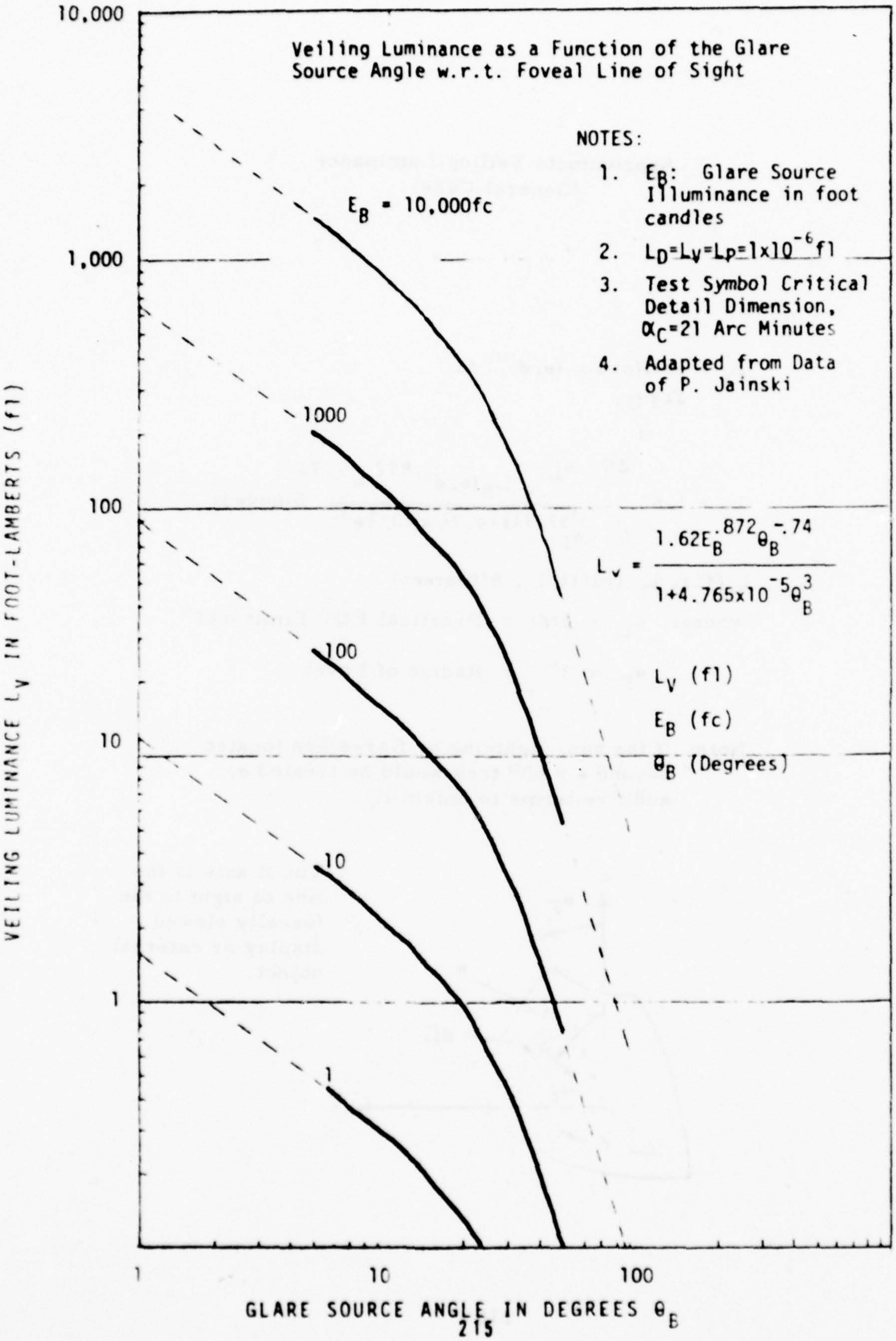
Definition of Perceived Luminance Tolerances for Automatic Luminance Control with Manual Trim Adjustment

LUMINANCE PERCEPTION RELATIONSHIPS





HUMAN FIELD OF VIEW


Veiling Luminance as a Function of the Glare Source Angle w.r.t. Foveal Line of Sight
NOTES:
1. E_B: Glare Source Illuminance in foot candles
2. $L_D = L_V = L_P = 1\times10^{-6}$ fl
3. Test Symbol Critical Detail Dimension, α_C=21 Arc Minutes
4. Adapted from Data of P. Jainski
E_B = 10,000fc
1000
100
10
1
$L_V = \frac{1.62 E_B^{.872} \theta_B^{-.74}}{1+4.765\times10^{-5}\theta_B^3}$
L_V (fl)
E_B (fc)
θ_B (Degrees)
10,000
1,000
100
10
1
1
10
100
VEILING LUMINANCE L_V IN FOOT-LAMBERTS (fl)
GLARE SOURCE ANGLE IN DEGREES θ_B

Approximate Veiling Luminance
(General Case)

$$L_v = \int_{\Omega\, FOV} f(\theta)\, L_B(\theta, \phi)^m \, d\Omega$$

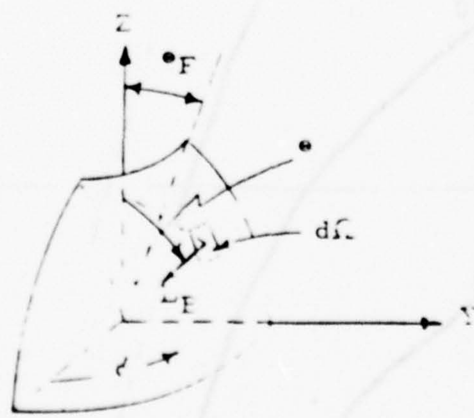
$$L_v = 1.62 \int_0^{2\pi} \int_{\theta_F}^{\theta_L} \frac{L_B(\theta, \phi)^{.872}\, \theta^{-.74}}{57.3\,(1+4.76 \times 10^{-5}\theta^3)} \sin\theta\, d\theta\, d\phi$$

L_v (fL), L_B (cd/ft^2), θ (Degrees)

where: $\theta_L = g(\phi)$ = Practical FOV Limit $\approx 60^\circ$

$\theta_F \approx 3^\circ$ = Radius of Fovea

Note: If the sun, lightning or flares are located beyond $\theta = 60^\circ$ they would be treated as additive terms to obtain L_v.



The Z axis is the line of sight to the foveally viewed display or external object.

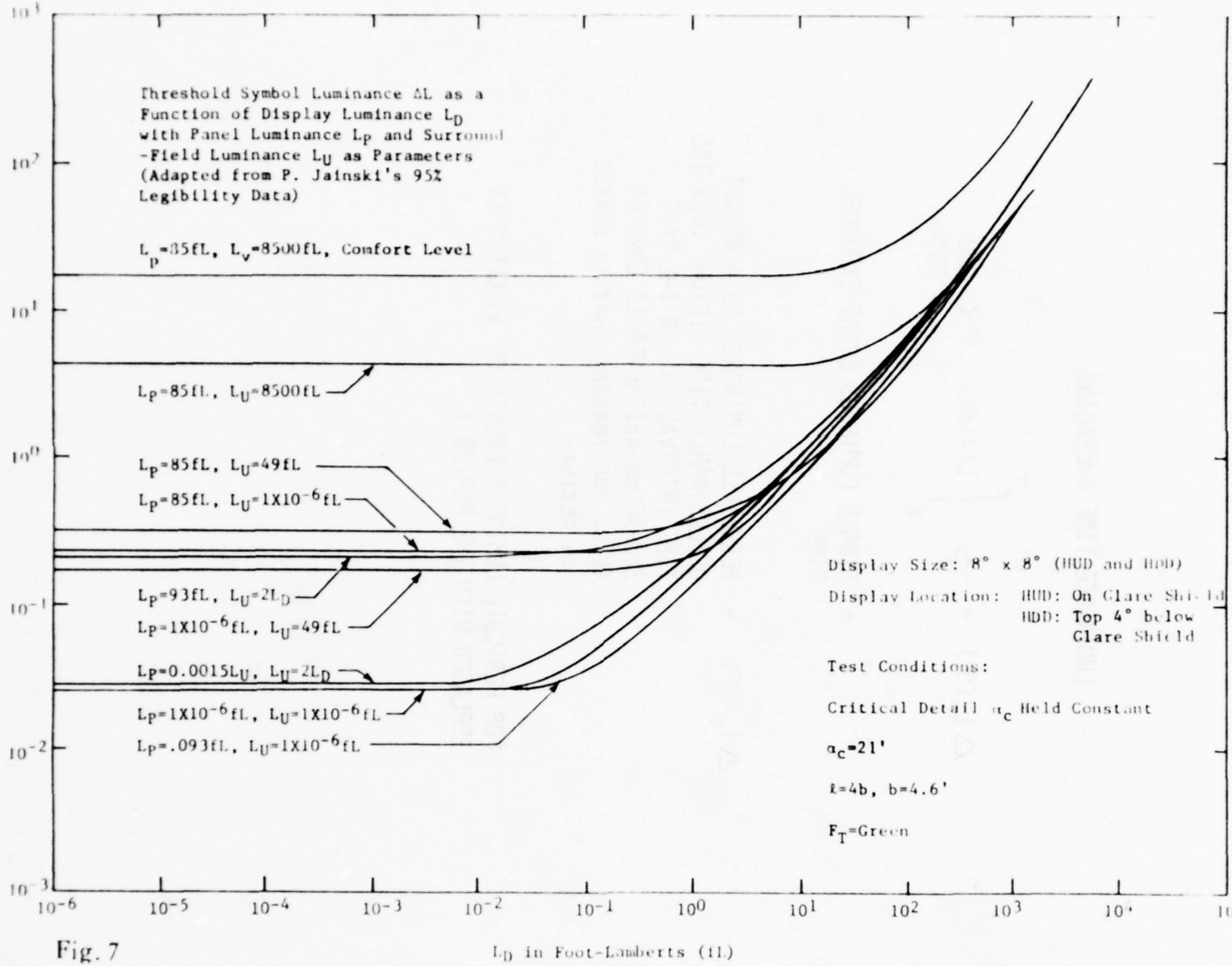

Threshold Symbol Luminance ΔL as a Function of Display Luminance L_D with Panel Luminance L_P and Surround -Field Luminance L_U as Parameters (Adapted from P. Jainski's 95% Legibility Data)
L_p=85fL, L_v=8500fL, Comfort Level
L_P=85fL, L_U=8500fL
L_P=85fL, L_U=49fL
L_P=85fL, L_U=1X10^{-6}fL
L_P=93fL, L_U=2L_D
L_P=1X10^{-6}fL, L_U=49fL
L_P=0.0015L_U, L_U=2L_D
L_P=1X10^{-6}fL, L_U=1X10^{-6}fL
L_P=.093fL, L_U=1X10^{-6}fL
Display Size: 8° x 8° (HUD and HDD)
Display Location: HUD: On Glare Shield
HDD: Top 4° below Glare Shield
Test Conditions:
Critical Detail α_c Held Constant
α_c=21'
ℓ=4b, b=4.6'
F_T=Green
ΔL in Foot-Lamberts
L_D in Foot-Lamberts (fL)

Fig. 7

LUMINANCE TIME AVERAGING

$$\Delta L_p(\tau) = \frac{1}{\tau} \int_0^{\tau} L(t)\,dt, \quad \tau < 200 - 300\,\text{ms}$$

τ = SINGLE LUMINOUS EVENT EXPOSURE TIME

$\Delta L_p(\tau)$ = PERCEIVED LUMINANCE AS A RESULT OF LUMINANCE TIME HISTORY OVER THE TIME INTERVAL τ OR THE PAST 200-300MS WHICHEVER IS GREATER (E.G. FOR IMAGERY THAT IS STATIC ON RETINA)

FOR PERIODIC LUMINOUS EVENTS OF $f >$ CFF, τ IS REPLACED WITH THE PERIOD T.

TRI SERVICE DISPLAY WORKSHOP

JAN. 1979

MODES AND TASKS

W. L. CAREL

The following is a text that annotates the viewgraph package. The description is minimal but should be sufficient to explicate the figures.*

Figures 1-5. The sources of information in piloted aircraft have progressed from the highly "pictorial" in the beginning of flight, through dedicated steam gauges, to display systems that may once again be "pictorial" and act as natural surrogates for direct vision.

Figures 6-7. The trends in cockpit displays re-open issues of information requirements, the proper ways of coding information, and optimizing the exploitation of sensor imagery.

Figure 8. There is a hierarchy of pilot derived display criteria that may be used to screen and evaluate display candidates.

Figures 9-10. The functions of displays are to satisfy the operational needs of the pilot and to convey information about the system state or the world explored by the mapping sensors with minimal perceptual and cognitive ambiguity.

Figures 11-14. A review of the evolution of displays, types of displays, requirements established by sensor complements, and the operational utility of representative sensors.

Figures 15-18. Examples of real beam forward looking ground mapping radar. Taken from A-6. Good for landmarks and large fixed targets.

Figures 19-20. Examples of high resolution synthetic aperture radar. Good for tactical targets.

Figure 21. Example of FLIR imagery.

*[Editors note: The following figures were omitted from the proceedings because the quality was too poor for reproduction: Figures 2-5, 15-21, 24-27 and 29-30.]

Figures 22-23. A display system includes more than the monitor; significant advances have been made in processing. This permits greater flexibility in choice of symbols, graphics, and the processing of sensor imagery.

Figure 24-26. Examples of current symbol sets for airborne use.

Figures 27-29. Examples of highly pictorial computer graphic displays that we may expect to be available during the next decade.

Figure 30. Example of processing of sensor imagery with a view towards enhancement.

Figure 31. Display capabilities for the mid '80's.

Figure 32. Self-explanatory.

Figure 33. The basic visual function that provides the basis for the following analyses.

Figures 34-35. One of the issues for use of the HUD is the utility of the device for display of sensor video. These charts illustrate the analysis.

Figure 36. For a selected spatial frequency this shows how the perceivable gray shades decreases with a decrease in adaptation level. It also shows why it's hard to extract detailed information from a display that is dimmed down.

Figure 37. A rather fanciful but by no means radically exaggerated indication of the range of display sizes desirable for optimal operator performance.

TRI-SERVICE DISPLAY WORKSHOP

MODES AND TASKS

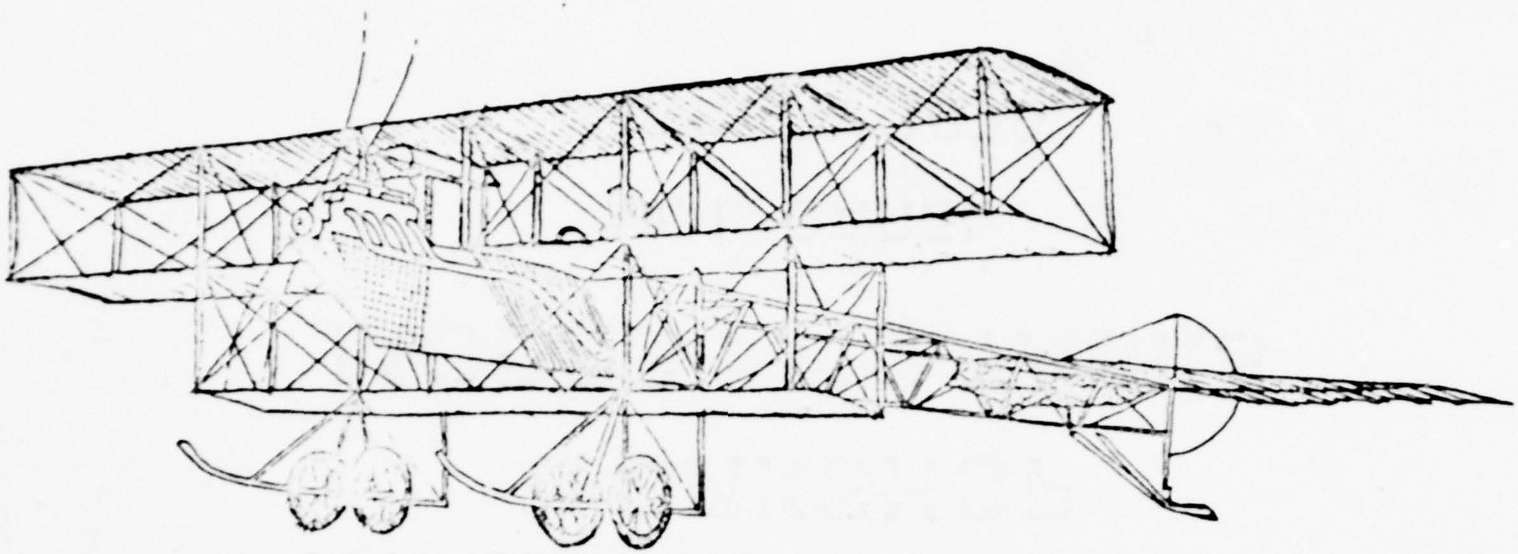
W. L. CAREL

JANUARY 1979

VG J11

THE WIND AND THE EARTH

VG 6252



AUG 1977

FIGURE 1

COCKPIT TRENDS

VG-2443

- MULTI-FUNCTION DISPLAYS
- MODE CONTROL AT SYSTEM LEVEL
- INTEGRATED INFORMATION
- DIGITAL AVIONICS
- EXTENDED USE OF MAPPING SENSORS

FIGURE 6

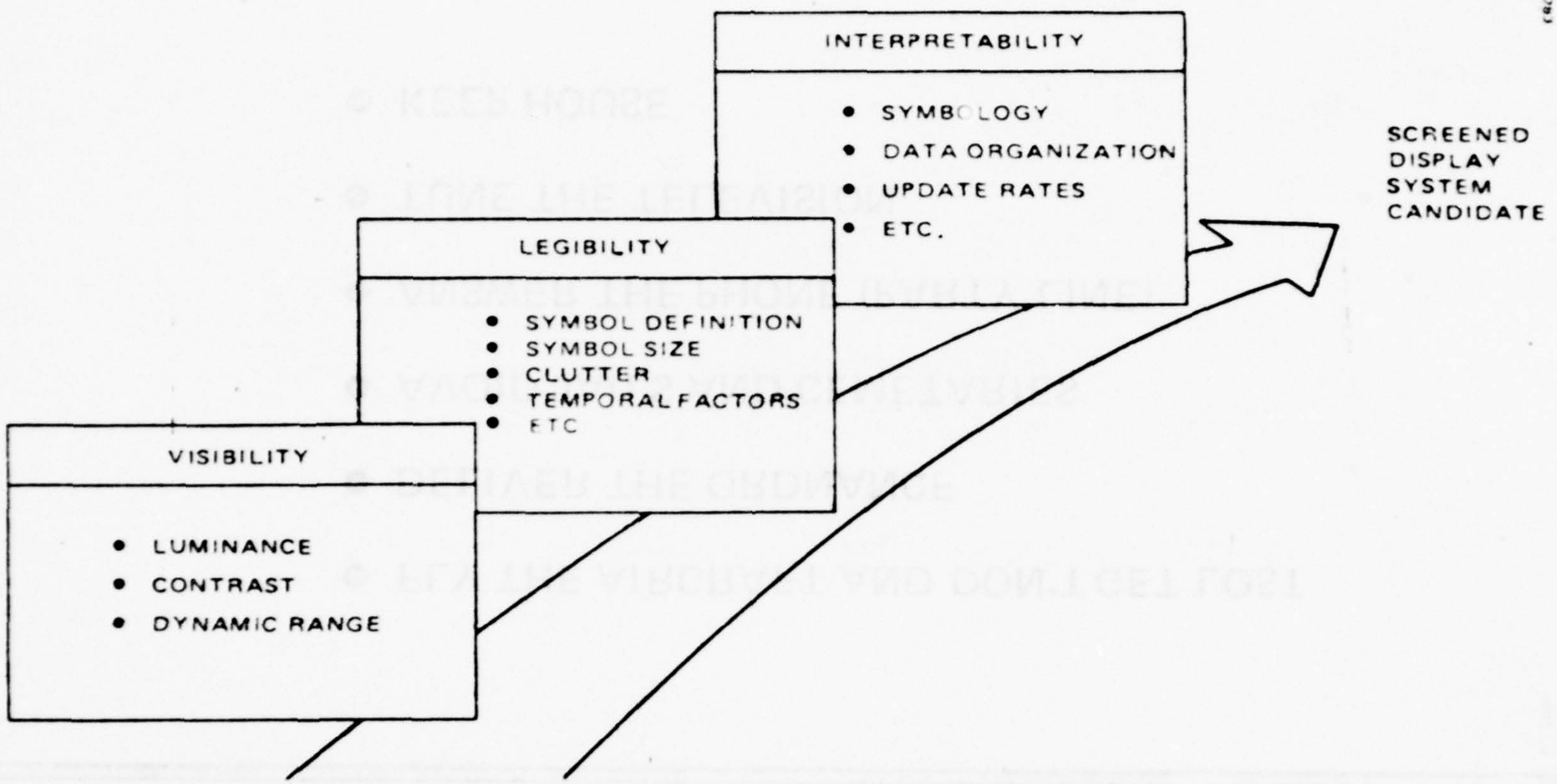
VG 1/6

KEY FACTORS IN COCKPIT DESIGN

- SENSOR COMPLEMENT AND LIMITED SPACE DICTATES MULTIPURPOSE DISPLAYS
  - SYMBOLOGY
  - SENSORS
  - CARTOGRAPHY
- PILOT "TIME AVAILABLE" AND SYSTEM COMPLEXITY DICTATES INTEGRATED SYSTEM CONTROL LOGIC

FIGURE 7

PILOT DERIVED CRITERIA FOR DISPLAY SCREENING AND EVALUATION



AUG 1977

FIGURE 8

SOME AIRBORNE TASKS

VG 7100

- FLY THE AIRCRAFT AND DON'T GET LOST
- DELIVER THE ORDNANCE
- AVOID JAILS AND CEMETARIES
- ANSWER THE PHONE (PARTY LINE)
- TUNE THE TELEVISION
- KEEP HOUSE

MARCH 1978

FIGURE 9

THE EXTENSION OF VISION

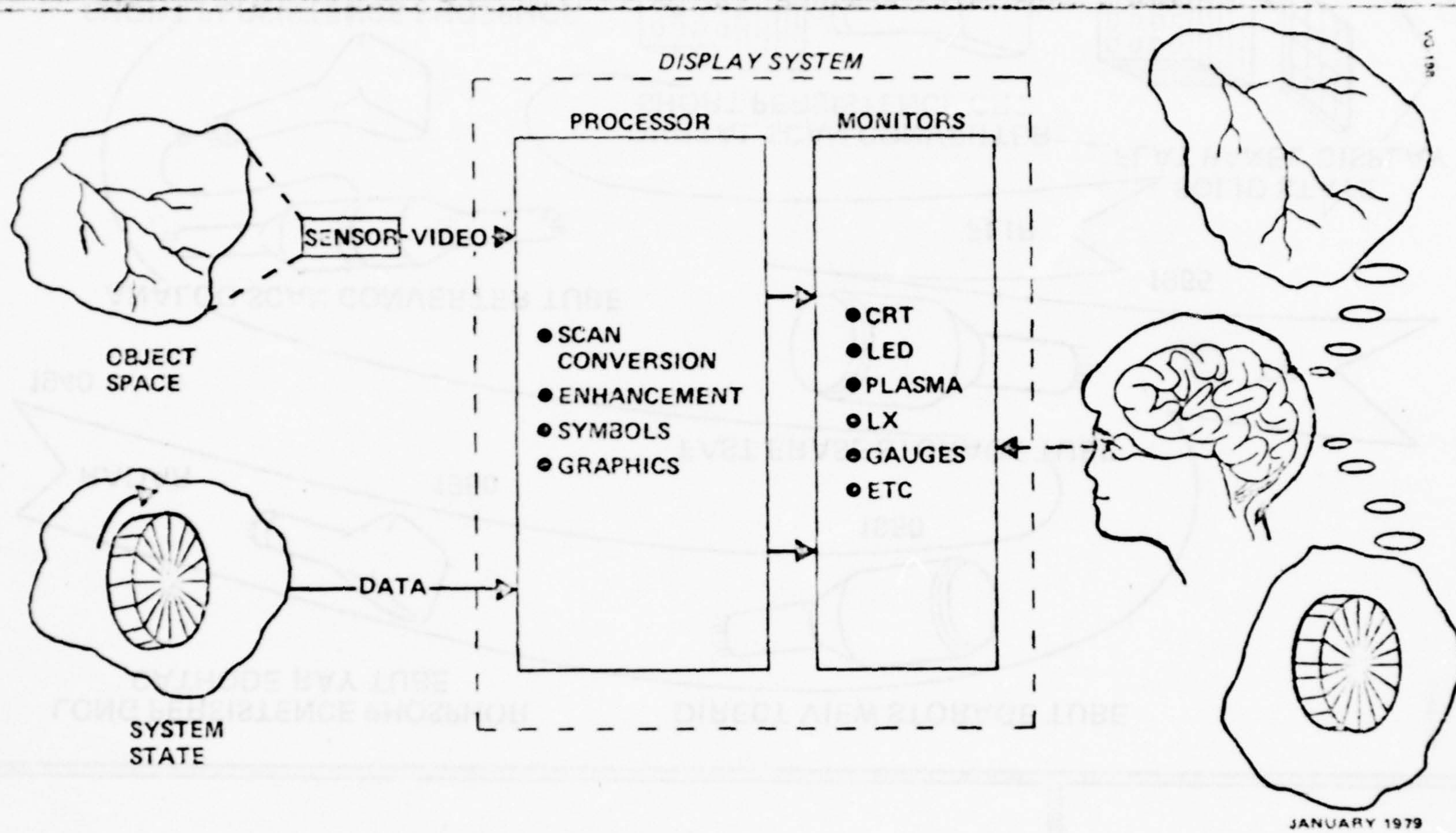


FIGURE 10

EVOLUTION OF SENSOR DISPLAYS

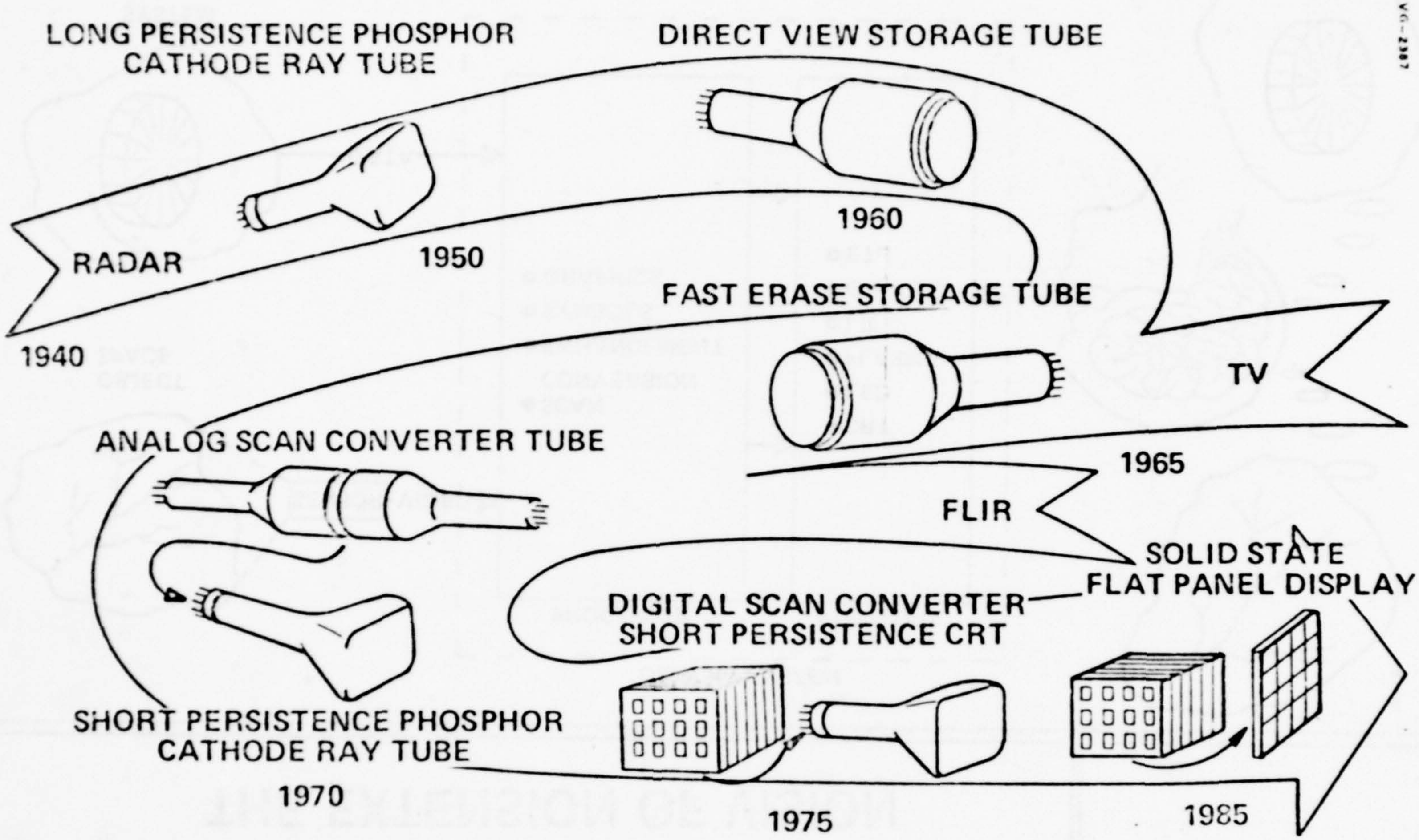


FIGURE 11

FUNCTIONAL DISPLAY CATEGORIES

VG 7741

- HEAD UP DISPLAYS, SIGHTS, HELMET DISPLAYS
- VERTICAL SITUATION DISPLAY, FLIGHT INSTRUMENTS
- HORIZONTAL SITUATION DISPLAY TACTICAL INFORMATION DISPLAY, PROJECTED MAP DISPLAY, ELECTRONIC MAP DISPLAY
- SENSOR DISPLAYS – RADAR, IR, TV, FLIR, EW
- MULTI–PURPOSE (MULTI–FUNCTION, MULTI–MODE) DISPLAYS
- INSTRUMENTS/GAGES
- INDICATORS, ANNUNCIATORS, PLAQUES
- READOUTS

FIGURE 12

TYPICAL FRAME RATE AND RESOLUTION CHARACTERISTICS

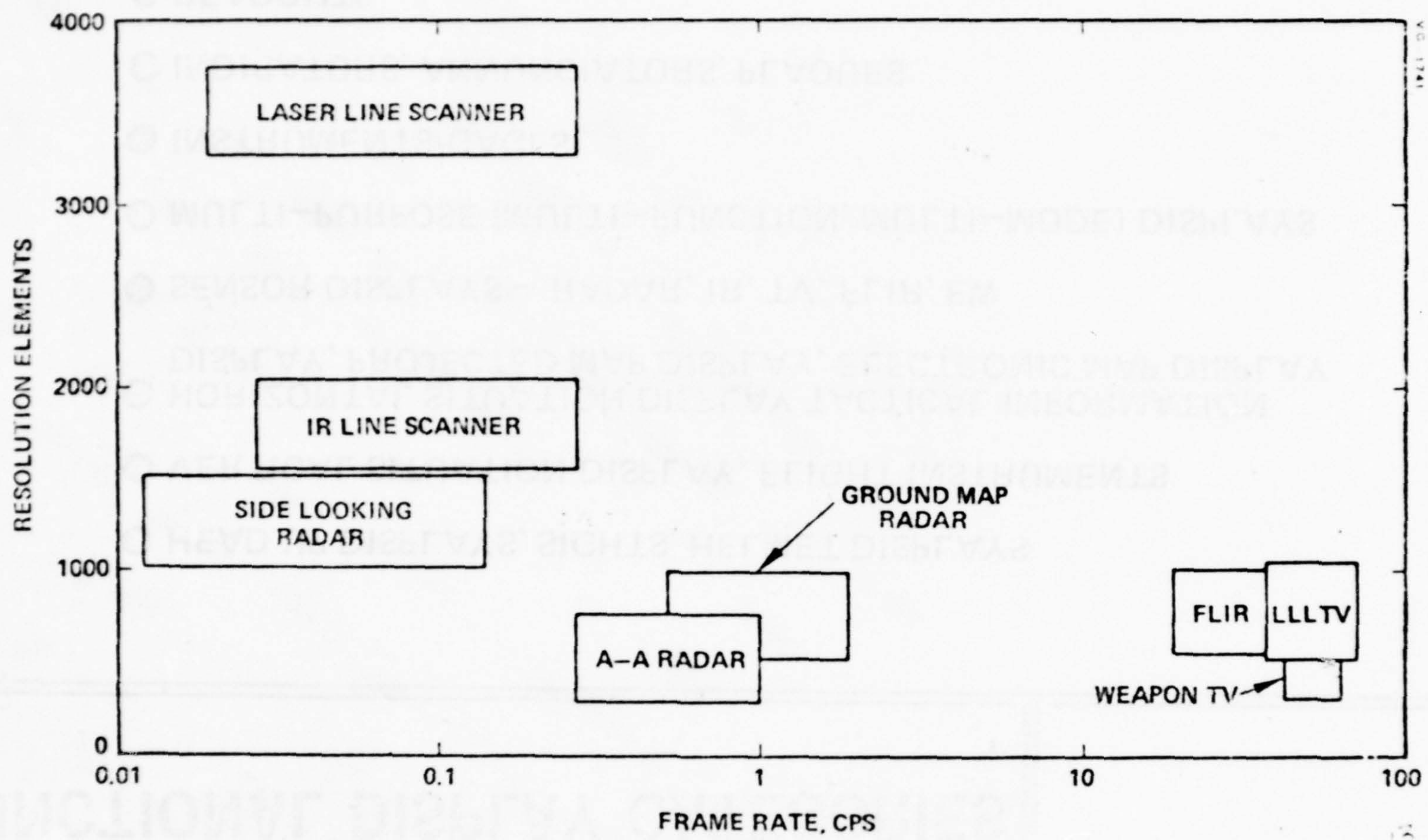


FIGURE 13

TYPICAL SENSOR CAPABILITIES

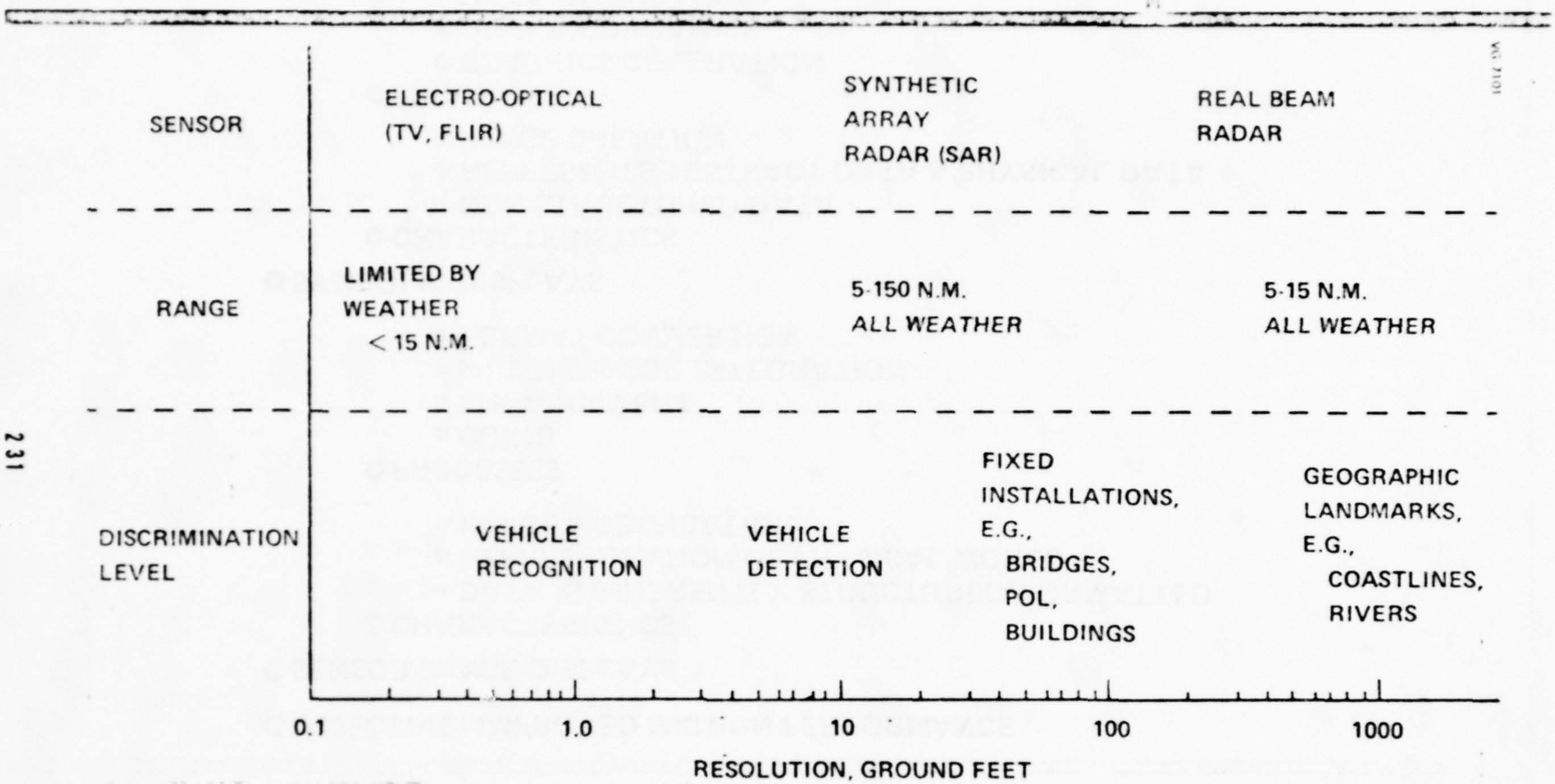


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FIGURE 14

DISPLAY PROCESSING - FUNCTIONS

- OBJECTIVE: IMPROVED MISSION PERFORMANCE
- SENSOR IMAGE DISPLAYS
  - CHARACTERISTICS
    - DATA IS INHERENTLY STRUCTURED/FORMATTED
    - REPRESENTATION OF PHYSICAL WORLD
    - IMAGE MODIFICATION
  - PROCESSES
    - CUING
    - ENHANCEMENT
    - MULTI-SENSOR INTEGRATION
    - FORMAT CONVERSION
- SYMBOLIC DISPLAYS
  - CHARACTERISTICS
    - NON-STRUCTURED DATA
    - REPRESENTS ABSTRACT DATA & PHYSICAL DATA
    - IMAGE CREATION
  - PROCESSES
    - GRAPHICS GENERATION
    - DISPLAY DYNAMICS
    - DATA INTEGRATION

DECEMBER 19

FIGURE 22

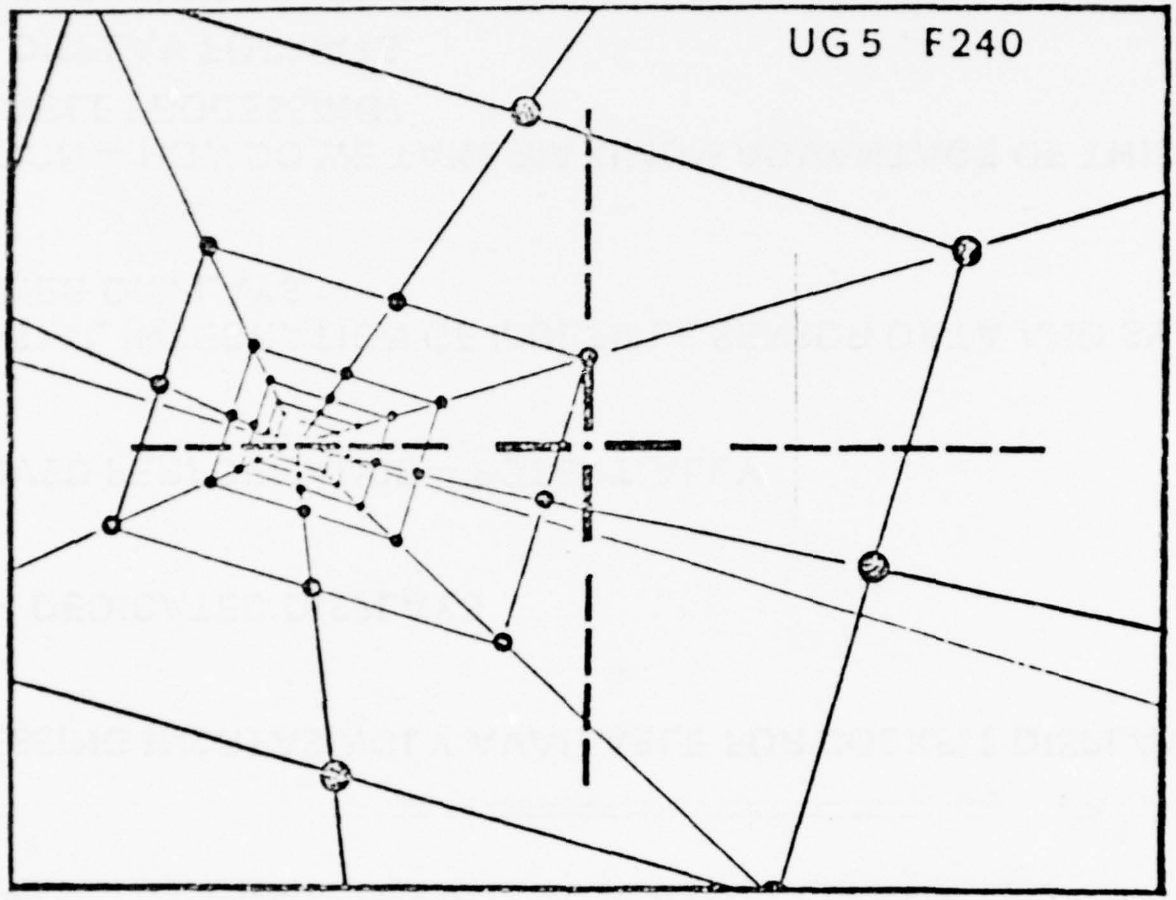
DISPLAY PROCESSING - IMPLICATIONS

- PROCESSING INCREASINGLY AVAILABLE FOR COCKPIT DISPLAYS
- FEWER DEDICATED DISPLAYS
- IMPROVED PERFORMANCE – POTENTIALLY
- POTENTIAL INTEGRATION OF MULTIPLE SENSOR DATA AND SYMBOLOGY ON FEWER DISPLAYS
- QUESTION – HOW DO WE TAKE MAXIMUM ADVANTAGE OF THIS AVAILABLE PROCESSING?
  - DISPLAY FORMATS
  - DATA INTEGRATION

DECEMBER 1977

FIGURE 23

TUNNEL DISPLAY



VG 6267

AUG 1977

FIGURE 28,

DISPLAY CAPABILITIES

HUD	VSD	HSD	HMS/D	AUX
• CONVENTIONAL OR DIFFRACTION OPTICS (WIDE FOV) • MONOCHROME CRT IMAGE SOURCE • STROKE OR RASTER SYMBOLS • VIDEO IMAGERY • PERSPECTIVE GRAPHICS	• DIRECT VIEW OR VIRTUAL IMAGE • MONOCHROME CRT • STROKE OR RASTER SYMBOLS • PERSPECTIVE GRAPHICS • FORMATTED VIDEO • INTERACTIVE (USED FOR SWITCHING CONTROL)	• FULL COLOR CARTOGRAPHY • PRE-FLIGHT ANNOTATION • IN-FLIGHT ANNOTATION • MONOCHROME CRT FOR ANNOTATION • VIDEO IMAGERY	• SIGHT ALONE, DISPLAY OR COUPLED • MONOCHROME CRT • STROKE OR RASTER SYMBOLS • VIDEO IMAGERY	• LIQUID CRYSTAL MATRIX (VIDEO) • ELECTRO-LUMIN-ESCENT

VG 197

JANUARY 1979

FIGURE 31

UNRESOLVED ISSUES, TACTICAL AIRCRAFT

VG-195

- USE OF HUD FOR VIDEO
- NIGHT VIEWING AND DARK ADAPTATION
- NEXT GENERATION SENSOR VIDEO

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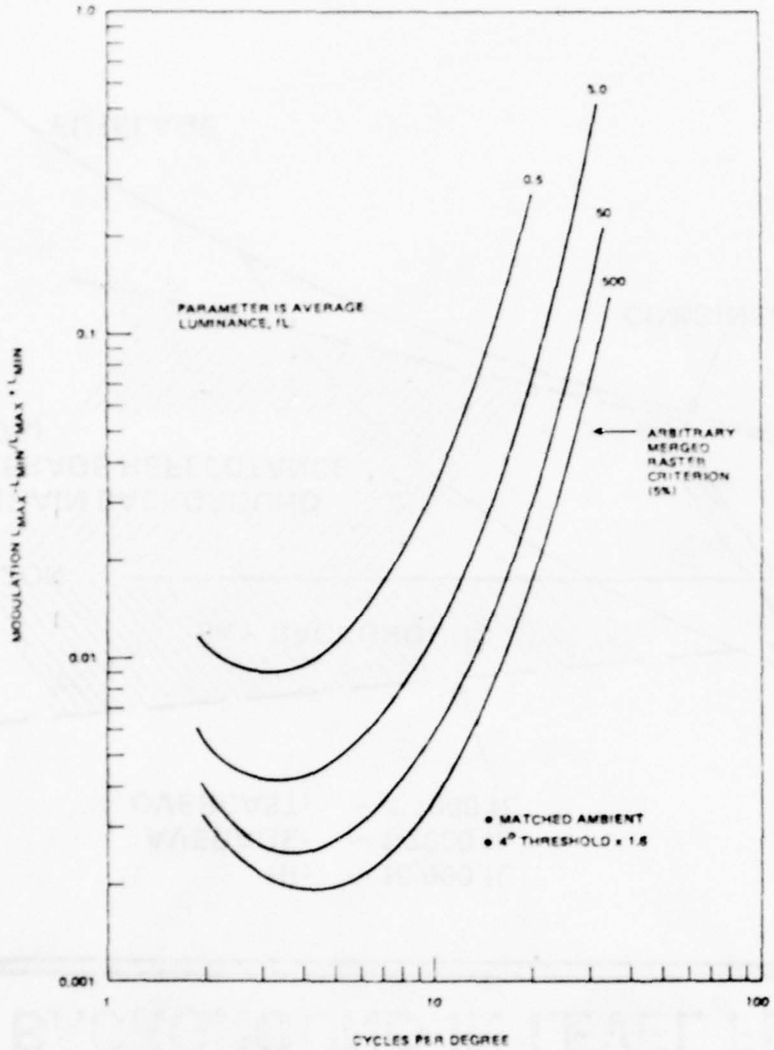
FIGURE 32

VISUAL MODULATION SENSITIVITY FUNCTION



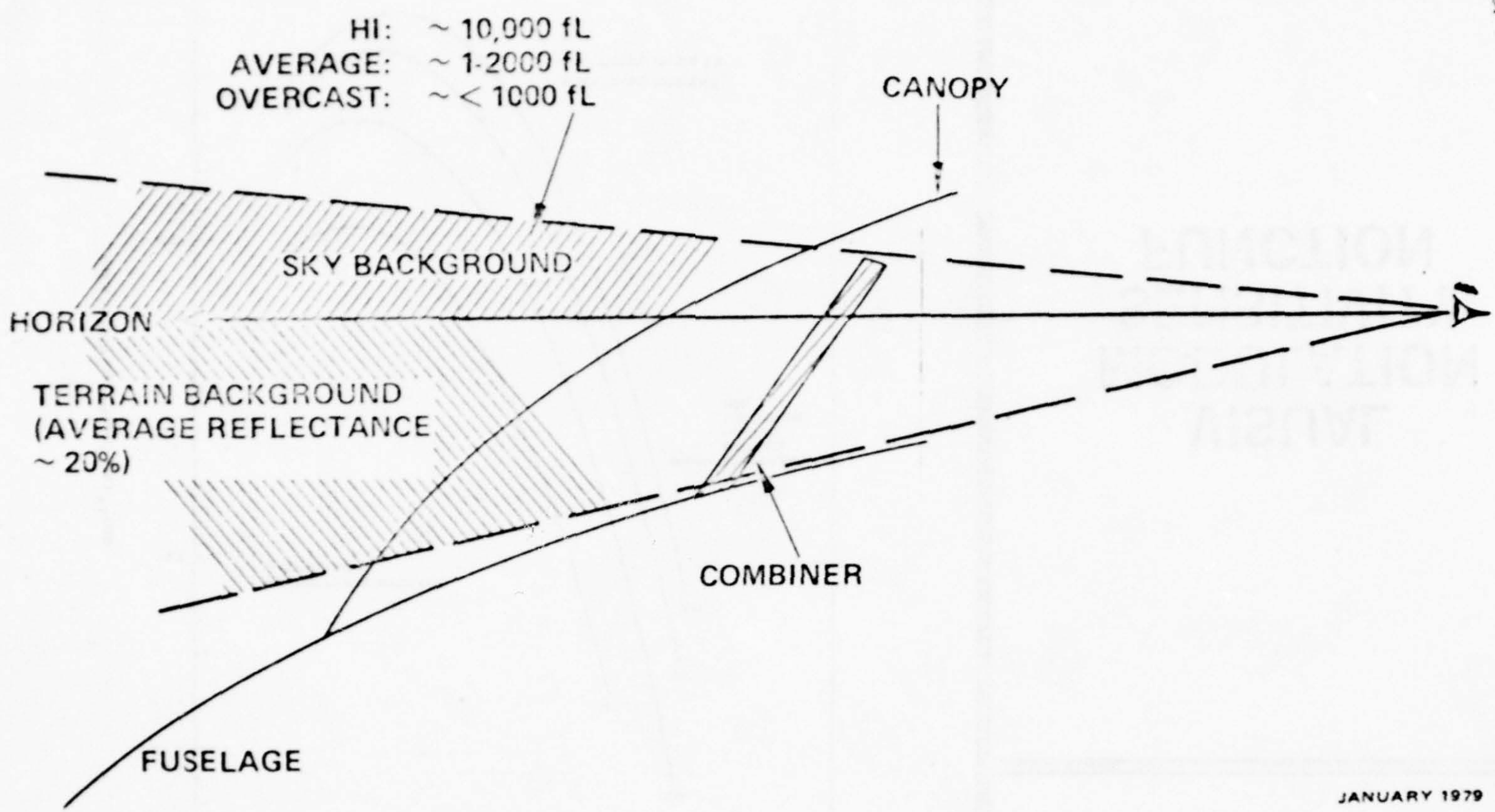
VG 191

JANUARY 1979

FIGURE 33

VG 194

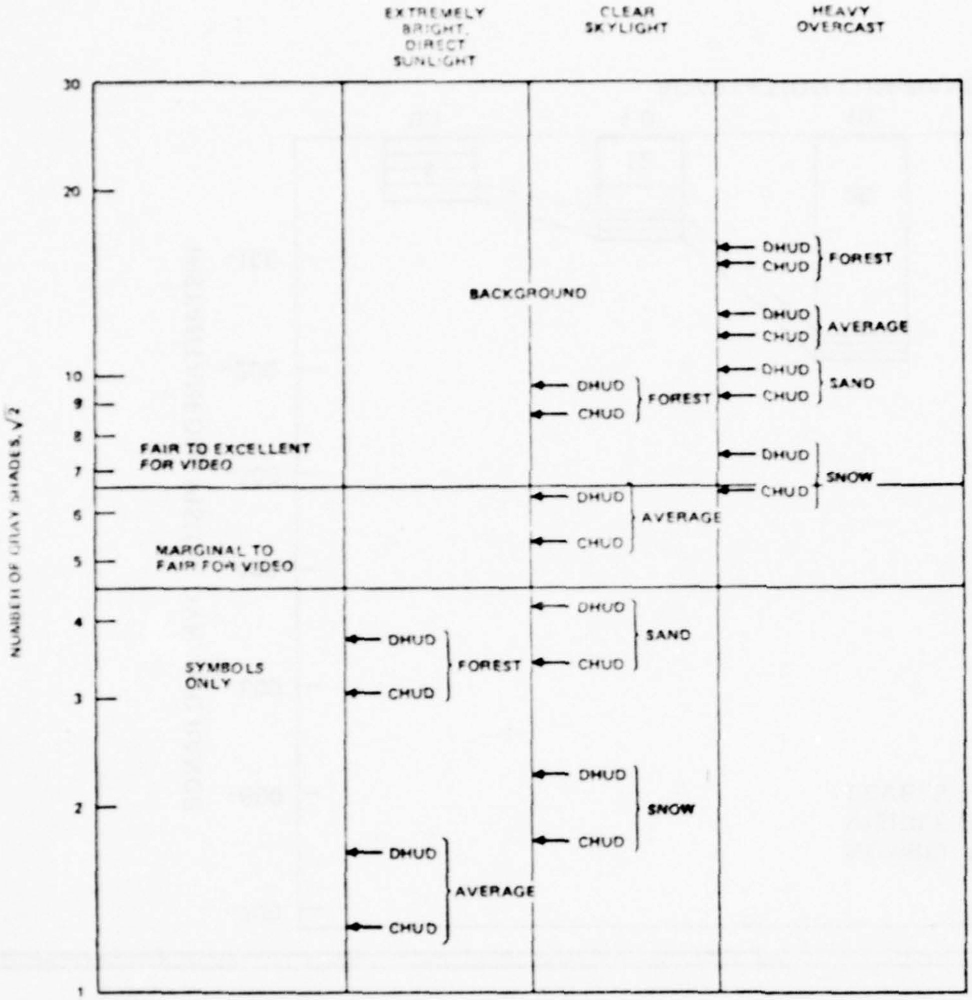
THE LUMINANCE OF THE HUD BACKGROUND IN LEVEL FLIGHT



JANUARY 1979

FIGURE 34

HUD GRAY SHADES



VG 123

OCT 1978

FIGURE 35

IT'S HARD TO SEE IN THE DARK

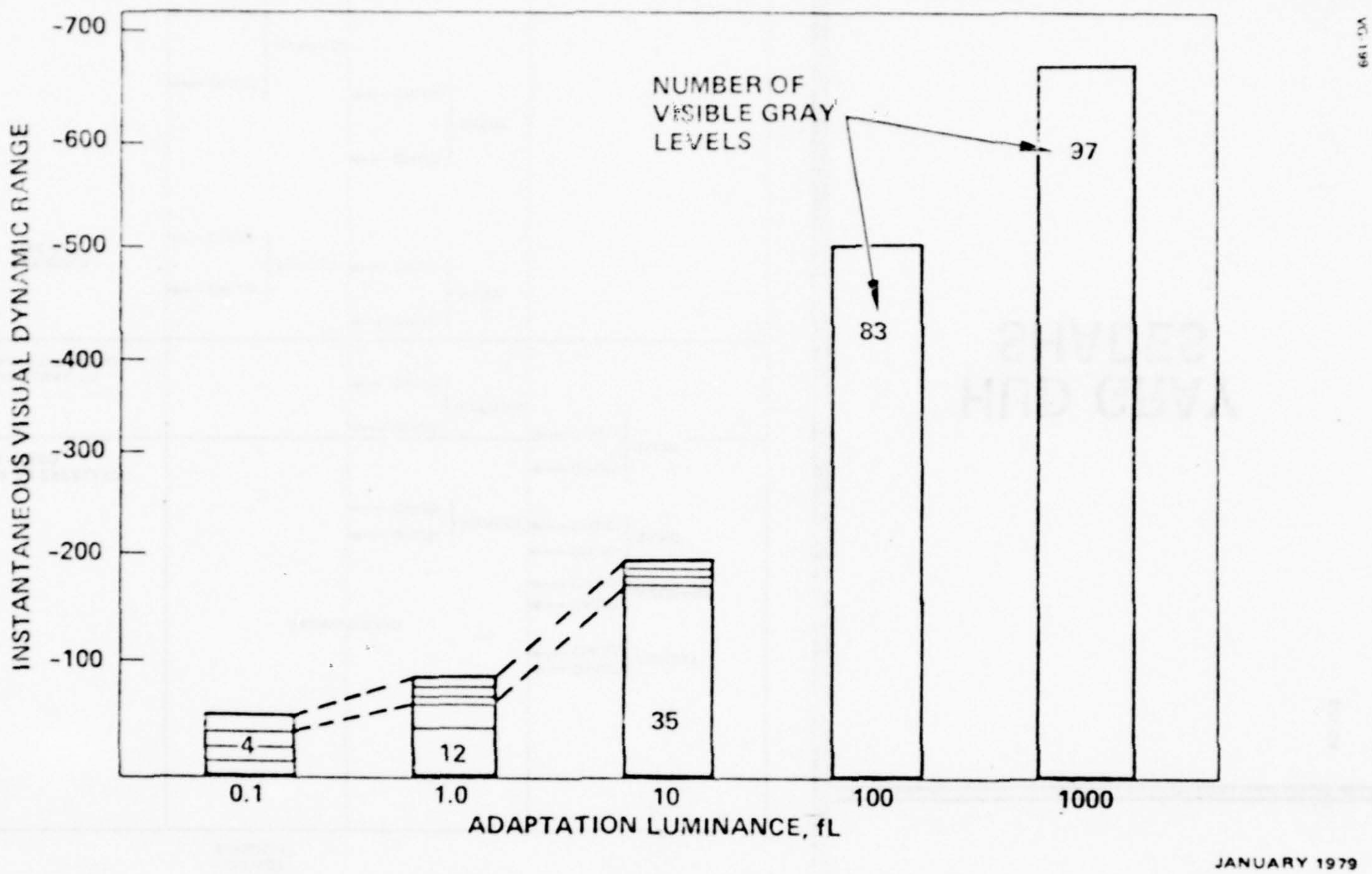
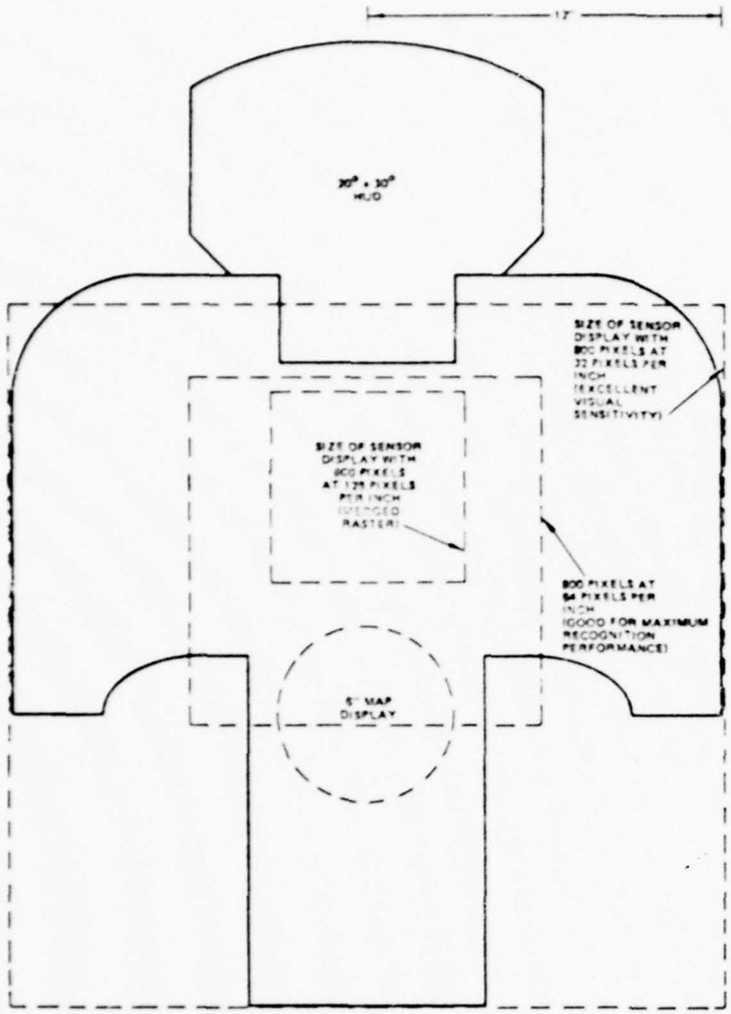


FIGURE 36



VG 127

SENSOR DISPLAY SIZES

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FIGURE 37

SESSION IV - DISCUSSION OF SESSIONS I, II, AND III

SESSION IV

Open Panel Discussion of Sessions I, II and III

Capt Robert Verona, USA, Moderator

VERONA: Yesterday we essentially had a mini-symposium with presentations on mission/doctrinal requirements, system requirements, and human factors. This morning we begin the workshop session of the Workshop that we're here for. The objective of this session is to extract and discuss the salient points from Sessions I, II and III, and hopefully, evolve a list of common tri-service display needs that are driving the advanced display requirements. We're going to be discussing several of the comments made yesterday and try to go a little more in depth into the rationale behind them. Please keep your comments brief and concise so that everyone has an opportunity to provide an input. This will keep the session moving and will give everybody a chance to participate.

Does anybody object to having this session recorded? They want to record so they can transcribe it and give everybody a copy. Does anybody have a particular objection? Okay.

Throughout the talks yesterday we heard several key phrases again and again. One of them was workload, reducing crew member workload. Another one was technology driving the requirements. Another was accelerated R & D. We talked about worse case environments, talked about long term and short term solutions. And one of the areas getting back to the real world was reliability, availability, and maintainability of all these new displays. I'd like to take each one of these phrases

in order to promote some discussion and put them back to you. I know that Colonel Patnode had some questions that he did not get a chance to address yesterday and I think we'll start with him. Yes, sir.

PATNODE: Was the Air Force influenced by pilot workload to look at two-seat versions of aircraft that originally had been planned as single seat? Where's Dr. Frick? You talked quite a bit about one versus two seats. I didn't hear any presentations that discussed the impact of a display/pilot workload excluding the mission workload point of view. Seems to me that one seat was a given in one case, and two seats was a given in another case. Not enough so called thinking, if you will, about the taskloading driving the number of seats in one way or another.

FRICK: I don't think that I could personally address that, sir. First of all we're not displays people. Our study looked at the mission requirements and then translated those into certain tasks that the crew had to perform. And then looking at the system output, assuming certain situations, the time lines were such that the crew members go to a one seat situation or go to a two seat situation. They would have to do certain things like looking at the heads up display then glancing down at the heads down display, and certain things were restrictive and making certain movements with their hands and feet. Because of this, there could be certain situations where they would have interference with all these factors working together. And therefore, considering the range of weapons, the required ranges that these weapons have to be launched from, the masking, and so on, that perhaps it would be better to change certain tasks or to have them automated. But as far as the

systems driving displays or the concepts, as you heard yesterday afternoon, that was beyond the scope of this study.

PATNODE: Our specific interest in that area is that we have a weapon system where the pilot in the back seat has a flexible turret, 30 mm, he can use with the weapon system while the co-pilot/gunner is launching the Hellfire missile. Bob Verona knows about it. I was wondering if you had some findings that might help us better organize the workload of the pilot, which is pretty significant when he's trying to keep the weapon system from bumping into trees and running into wires. Our problem, although we fly at very slow speeds and sometimes hovering, I think from a tasking point of view is very similar to your pilot's but for different reasons. Your guy is moving "x" number of feet, that only gives him 4 or 5 seconds to acquire the target and put the auto-tracker on it or whatever. Our guy has more time to do that function but he has other problems to worry about.

FRICK: More specifically we recommended that the target designation task, which we defined as the slewing of the cursor and so on to the target and then designating that target for weapon delivery, be made more automatic. And that direct voice control and the use of a helmet mounted sight and either an all heads up display or heads down display situation be considered in the cockpit. If anyone here has any disagreement with that or have any thoughts on this matter I'd like to hear from them. I'd like to speak to you.

VERONA: Okay. So we're saying that this goes back to, really, workload.

Are we talking about new display configurations or new display technologies? Going back to the worklaod, we say we can use an automatic tracker. That will help alleviate some of his attention requirements, if we have displays that maintain the appropriate contrast and brightness so that he does not have to play with those controls. We have an automatic technique of updating the sensor/display interface, if you will, so that the voltage levels are always at the optimum setting. If we give him a better, higher resolution display more matching his requirements he may not have to strain as much to pick out that small target.

PATNODE: The gut issue, Bob, is in the display technology and the stuff that backs that up. It seems to me that the only way they can get there from where they are is to do automatic image processing and select targets out of that processing rather than have a manual select. Maybe he has a manual override which sees that the system picks out a critical target that he doesn't want to engage, he doesn't have to engage it. It seems to me that is a given in a single seat attack, low altitude. I'm not talking about the clashes we've had in the past.

KAY: Maybe I can address it a little bit, Bob. For the F-16, for the advanced laser designator system that we're coming up with, we were integrating it with the fire control system of the F-16 itself. And ideally, the F-16 has a point of interest, whatever it chooses as the prime weapon, be it the radar or the laser designator or the weapons or the Nav system, whatever, everything it points to, you use this point of interest to slave your other sensors. So your interdiction-type target

that will be in the INS with a point of interest on the HUD, circled, with an arrow pointing at it will point the other sensors to it. The advanced laser designator will undergo automatic field-of-view changes and stuff like this, but you'll be able to, when the target is up there, get an indication that it should be locked on with a look down, and the crosshairs are on it, and there should be automatic tracking. We're integrating the whole thing into the present aircraft. It should indicate the target to the pilot, he wasn't going to sit there and search the display.

PATNODE: On an interdiction mission I can understand that. The big problem is picking out what the target is, and doing it in the matter of, as with the A-10, F-15, a matter of 4 or 5 seconds total exposure time. Find the target in clutter, slew the sensor on to it, get the autotracker indication, and hope that you haven't overflown it.

KAY: We're doing some simulation in the Martin simulator with the A-10 aircraft, a totally integrated system to find out, can he do it. The first group of studies we came up with, with the HMS and HMDs with a fixed FOV and ATAC kind of sensors to really define what's going on. (Non-transcribable segment.) That's as far as we've gone (non-transcribable). (Non-transcribable segment of about 1 minute duration.)

KING: In the helicopter area, I guess we've looked at it in the Navy, as a two part problem. One part I guess is outside the real area of this conference. But the first part, I guess, you solve first before you get into the display area at least for helicopters, "How automated are you going to make the flight control system?" That eases the pilot

workload and now he can spend more time with the displays. Once you've made that decision as to how automated that particular air vehicle is going to be, then you can work on optimizing your displays. But if it's a two part problem, it's interwoven, especially with a heads up or helmet mounted display which is also the primary flight control display with a lot of Navy aircraft. But you solve the electronic portion of the flight control, the pilot can put the plane on hover, just let it sit there on its own, then he can play around with the weapons, that's great. But we haven't been able to solve that problem yet in the helicopter area.

(Non-transcribable comments.)

ANONYMOUS: You can do it.

KING: You can do it but at a high price. And as program manager in the helicopter area I'm willing to pay the high price for putting in sophisticated electronic flight control systems.

(Garbled discussion by Colonel Patnode relating to question of automated flight control systems.)

VERONA: We heard another statement yesterday relating to the same area. Priority in technology should be in alleviating workload rather than improving target acquisition. Now we have an example in the "64" where we've got our target acquisition designation system. We've got three sensors available. We've got a FLIR with its two FOVs; we've got a direct view sight system; and we have a daytime TV, which gives the operator many alternatives. Now there's got to be a thought process that goes through that unless it becomes an automatic reflex which it sounds a

little complicated right now to be an automatic reflex, except through long periods of training on which system to use to do that particular job. And I think that's what Colonel Patnode mentioned yesterday; he doesn't think we need three, probably two out of three but which two out of the three. And right now they're all using the same, well not really the same, type of display. But you've got a heads down display where you put your head in the boot. Then you have the heads down display where you're looking at just the CRT.

PATNODE: With that in mind, let's not mislead people. Heads-down looking at this very tiny CRT for the copilot/gunner is a figment of a bunch of engineers' imaginations; they'd never fight a war that way. Really, what it is there for, in my mind, is a readout for the fault detection and location system, troubleshooting, and any guy, particularly at night, would not want that CRT illuminated. So that's why I put a knob on it, so you can turn the brightness to zero. I think that's the way most guys would fly, Bob. I think we make a fundamental error if we call that thing a heads-down, look-down type display. Because that thing is what, 2½, 3 inches diagonal, it's too small to use to fight a war, even though it's got absolutely beautiful detail. I do believe the display people make the contribution when they look at more than one sensor up on the same display which we are doing at Martin and Northrop. But if you could move telescope optics around like you move video around, you can simplify the display. The direct view optics is like a camera. There's no way to use the same "display" in direct view optics as we do with TV and FLIR.

For TV and FLIR it's fine, but not for direct view optics.

VERONA: But even there you may not be optimizing the display for the sensor, from both of those sensors. Anybody else have any comments they want to make?

BURNETTE: Yeah. The one thing I would hop on, I really didn't get to hop on but would have is "What is the human capable of in terms of looking at a display when we provide that to him?" We keep looking at these things. Well what sensors do we have, will the displays show that sensor and then we go back the other way, and it seems like the only improvements occur by accident. Somebody gets a little higher resolution in the sensor and all of a sudden you need a display to handle that. The fact is, if you cut a hole through the aircraft and look down through it, you get a lot better view than you could get with a magnification of a one video display, as long as you've got good visibility. And until we can provide that kind of resolution to the pilot on a heads down dipslay, how can we expect to acquire targets using the human as the detector of the target. Now the ideas about analyzing signal data, correlating it, comparing (a) the radar says I have a target, the IR says I have a target, the LLLTV says I don't, we go through a voting and decide hey we've got a target, we put the target on a display big enough so the guy can see it, there's no question that he can see it, he knows approximately where it is. That kind of thing basically doesn't involve the problems we're talking about with video displays. You can do that on vectorgraphics and you can do it in a lot lower light level as far as luminance on the display. You don't

affect his dark adaptation as much, and on that dark adaptation thing, this is now the night version of this thing, you're talking about one man. We have fantastic controls on everything in the aircraft except for lighting. And, in terms of the display, there's two ways of looking at that, when you're looking at it for information, it's luminance and you're looking at a small area. When you're looking away or not focused, it's lighting, and the lower it is the better dark adapted he is. The thing is when you go heads up, this glare/luminance thing I was talking about, you should be able with the systems we have now to detect if the head has gone head up and turn down the lighting. I mean, when the guy goes head up, if it's a single seat now, I mean you can't turn everything off in the cockpit with another guy sitting there but then that's a different situation. But turn down the lighting, you don't have that source anymore. If you look at the data they adapt rather rapidly from the sparse kind of lighting thing you have in a cockpit. So you do have a chance of getting relatively low levels if you turn off the lighting in there you've got a chance of getting way down. Now that's sort of an analysis thing that I'm not capable of doing, I'm just throwing this out. I'm not saying this is the way to go but it should be considered. There are a number of other things that you could play around with in the same manner.

ANONYMOUS: When you go the other way now, where you look back in the cockpit, you realize that the guy has been looking out so you bring the light up higher than what he would normally have, and you can gradually decrease it because he's going to be doing re-search.

BURNETTE: When you're dark adapted, you're already set up to the

absolute lowest luminance. So now you control it at that point and then basically what you need is a computer. This is not hard to keep track of, you look at what he's been looking at for the last five minutes and you move the luminance control of the display in accordance with that.

VERONA: We've got some problems in that area though. For example, in our "64's" we've been going through our CRT specification and night acceptance. We've got an ultimate gray shade requirement; so whenever you go to very low luminance levels you don't have the necessary amount of gray scale as measured by some technique.

BURNETTE: I agree.

BRINDLE: Another thing to keep in mind, that guy is doing this (moves head about) he's not staring at the display and then glancing out. That guy's got a lot of head motion, a lot of short, choppy motion and in many cases its not only head motion but eye motion. You're talking about automatically controlling either and/or the display.

BURNETTE: Well if he's acquiring the target outside by pulling his head up and just glancing through the atmosphere, this basically is a sort of a problem because there isn't any way you can do anything about it. The target outside is either bright enough to acquire under very short duration exposure or it's not. And there is not time for any kind of adaptation in what you just described.

BRINDLE: Right.

VERONA: For the ranges we're talking about at night, we're certainly not talking about very many visual target acquisitions anyway.

SCHLAM: Bob, I'd like to get back to this point of reducing operator

workload as opposed to optimizing and increasing target acquisition. I think it's an extremely critical and important point. I'm a technologist but I want to make it clear, we shouldn't improve technology for the sake of improving technology. I wrote down a quote, I think you said it, Bob, anyone could have said it, "optimize the display for the sensor." You don't necessarily want to optimize the display for the sensor, you want to optimize the display for the operator to use in doing his job. Just because your sensor gives you higher resolution, maybe you don't want your sensor to be high resolution, because the last thing you want to do is concentrate on optimizing the display for the sensor. I think this question of automation, and information processing is a very important concept and again, do the things for the operator, it has nothing to do with sensor/display optimization.

VERONA: Elliott, as a good example of that, in our FLIR imagery, if we're looking for hot targets, looking for a tank out there, we may not want to see all of the other little nitty gritty details until we're ready to identify it. We want to pick it up first, we don't necessarily want all that information, all of the trees and all of that. We want to see that bright spot as we standby and have it jump out at us, and then you can go out and...

SCHLAM: Instead of adding information, let's reduce information to just the critical information.

KAY: Going along those same lines, in PAVE TACK, the displays, you're talking about the same thing. You've got two CRTs used for telemetry, the weapons, the radar and the FLIR. And every time you flip those

things, they require readjustment. (rest non-transcribable.)

ARMSTRONG: Yeah, I want to come back to that. Somebody mentioned the contrast/brightness control earlier. We recently had a meeting with General Dynamics and invited one of the local test pilots. The meeting was with regard to the laser designator interface. One of the greatest things that came out of that meeting, that the test pilot thought of was with regard to switching. The problem of switching back and forth between the radars and the pod and each time having to adjust the brightness and contrast. That's a problem we haven't solved yet.

FRICK: That's part of workload and I think part of the workload problem.

SCHLAM: (First part non-transcribable)...that's a problem that's double, that doesn't imply any technology breakthrough by and large.

(Non-transcribable segment.)

VERONA: We're implementing some of that, that takes care of gain and level at the sensor supposedly to maintain some uniform optics. Now both of our associates are using different techniques in setting up the display so that you always have the right amount of video and unfortunately we get into a competition sensitive area.

ANONYMOUS: I think that the problem you have is that in the radar mode they like the display brighter than when they are in a FLIR mode. (Rest non-transcribable.)

KING: On the F-18, when we gave the pilots the option to put the whole cockpit on the same ambient level, displays, indicators, etc., they did not want that. They wanted the automation of where everything would go to certain levels but they also wanted the option to be able to push

one display up and one down, especially when we had radar on one display and FLIR on the other. They preferred to make one brighter, I guess, as a primary display they wanted to look at in detail and they wanted to have the other one a little dimmer. They wanted that option.

BURNETTE: Right, with one point. On the existing, multiexisting CRT systems that I've seen, I've curved their emitted luminance which gives essentially along one of those curves a curve of constant legibility. And that does come out, it appears to me, to be the same thing ostensibly when you take people in and show them something controlled in this manner and you turn off the lights. They say, hey, it hasn't changed, maybe there's something wrong with it, it should be brighter now. But the point is that our present controls on CRTs do not do a good job of control. If it has an automatic luminance control, it almost never controls to give the pilot even close to the same legibility over a factor of like 100 range of background. Okay, that's an important aspect of it. You have some people coming to the conclusion that you don't need it. Part of that conclusion comes from the fact that you can tolerate a huge amount of luminance variation in the daytime for instance, and you just let it go away at night and you actually have lower legibility. What I think we're talking about here, in terms of especially dark adaptation, is that you want it as low as you can get it. I grant the gray shades I was talking about yesterday, you have to use a much higher peak brightness, then you've got a good gray shade display. But how many video displays is he going to be looking at simultaneously because the rest of the cockpit can be, like for normal flight control, a lot dimmer. In fact

each of this different size, the goal is we've found, not to get uniform luminance throughout the cockpit it's uniform legibility, and if you have a very small dial and a very small number it might have to be a little bit brighter to get it in the eye. Anyway, all these kinds of things have to be factored in. But I think you have the information to do that. No incentive, no one's even thought about doing it with, in a systematic approach with the money there to do it though the companies can naturally have it done. And we've found in just going from a standard GFE cockpit which generally has a huge variation in the lighting levels from something that was fairly uniform, we've got a tremendous improvement in the ability of the guy to look out and see the target.

(END OF TAPE)

WARUSZEWSKI: (First part not recorded)...We have asked for a 10% uniformity within a given mode, but also when you switch modes, radar to FLIR or whatever, the brightness shall not change by more than 10%. So you can sort of fine tune your displays as far as the inputs and put limiting resistances or whatever you have to tune your sensors to the display so you don't get a change when you go from one mode to another by more than 10%.

VERONA: Well this pretty much goes into the systems approach. If we do get a good system's integrator that looks at the whole package, then you're a little more than likely to get a better system. As we switch from video, you don't have that on your commercial TV and we shouldn't expect it on our high cost avionics. The sound may be a bit louder on your commercials at home and your color may be just a little different

but certainly you don't get any big flashes at you that you have to get up and adjust the brightness and contrast controllers. That's taken care of, you should have it taken care of.

ANONYMOUS: I don't think you want an automatic control. I think you want the operator to be able to set it where he wants it and then leave it alone.

BURNETTE: Right, thereafter it's controlled automatically.

ANONYMOUS: When you go from FLIR to radar, how much do you want that to be within?

ANONYMOUS: It should be within 10% of what he sets up, that's what he said, right?

VERONA: But what he sets up may not give you optimum performance, I think.

SNYDER: I appreciate the logic for each pilot wanting to set his own pedastal and we all do it with our home TV and everything else. But if there's one thing we've learned over the years, it is the fact that there is a right setting for such things for a given job. The last thing you want to do is have those controls out there in the cockpit. There's a study from 1954 that shows that once you optimize brightness and gain of the display and leave it alone, the pilots will in fact do better than if you let them fudge with it. And there's absolutely no reason for each pilot to select his own unless he's got an abnormal eyeball.

OHLENBERGER: Not only that, you've got too many variables it appears to me. You're talking about the ambient light on the outside, changes in optics, switching from day, day or night, you have too many variables,

I don't see how the heck you'll ever do it. When you try to do it automatically you have to do it according to that individual or give him a bunch of knobs. We've got too many knobs in the cockpit the way it is.

SNYDER: The sad fact of the matter is, with a normal CRT display where you have so called brightness and contrast control, there is one combination of those two controls which gives you the most uniform sinusoid, that is, the best gray scale rendition. Anything other than that unique combination results in degradation in the system. To give a guy two controls which necessarily are interactive and ask him to find what he believes to be optimal because he is a perfect pattern analyzer is absurd. You are much better off if you can determine what is optimum beforehand.

OHLENBERGER: Another thing you might get into is the fact that you may have a backup system in the cockpit, say as an example the night vision goggles. Now, I've worked somewhat with that system and it's a real bear. Apparently the CRT does not in some way permit you to turn the gain down enough, so you have to use a compensation device, if you will.

SNYDER: But that can be automated much better.

OHLENBERGER: What I'm saying is that you may have to have two settings.

SNYDER: True. Apparently you have to have a multiple setting number depending on ambient lighting. However, once you determine what those settings should be, they should be automated and not subject to pilot control.

WARUSZEWSKI: How much do you want to reduce the reliability of those displays by putting in all that automation?

SNYDER: Gee, if you can't build a reliable AGC circuit we're in deep trouble.

ANONYMOUS: The contractors say it costs a lot more money to increase reliability.

VERONA: Okay, Dr. Frick.

FRICK: That brings up another point. Speaking as a layman in displays, it seems to me the purpose of displays is to enable someone to make a decision. In our place, we think in terms mainly of FOV, and what's within the FOV and being able to have enough information on the target that you can make a decision on whether to deliver the weapon or not. You know that brings to mind, what about automatic pattern recognition? I haven't heard anyone talk on that yet. Is there much work being done on that? In other words if you can take that part of the decision making process away from the pilot, you know that would help.

VERONA: That essentially gets you into another arm of the Tri Service Night Vision Technology Panel.

SCHLAM: Wait a minute. I don't think that's another arm at all. I think that's one of the main things we're talking about here. Again, I think, as I mentioned the day before, don't make your displays better but make your system better. And, if making your system better means putting certain automatic features in it, be it character recognition or what have you, certain things are doable, they may be hard but they're doable. We might be able to recommend that this is the type of thing that should be looked into as far as pilot workload is concerned. Rather than blame the displays for the pilot being overloaded, maybe it's the system.

This question of system integration is extremely important; you have to tie the whole system together and part of that system is the processor. Maybe the problem is in that processor, not in the sensor and not in the display or somewhere else.

HAKE: That's right, Elliott. When we talk about the Second Gen FLIRs this afternoon, that type of work is being done particularly in the Army's ATAC program. They are developing an autocuer and the Air Force has an autocuer, autoprocessing programs that are either ongoing or getting started to try to automate a lot of this stuff; to help select out the wheat from the chaff and present that type of information on the display so the operator doesn't have to do all this by himself. It may be part of the solution.

ANONYMOUS: Who's doing that work?

HAKE: Well we're doing some of the work at the Avionics Laboratory and the Night Vision Lab is doing autocuing work as part of their ATAC contract.

SCHLAM: You know things like that may be hard but they're doable. We have integrated circuit technology, by and large, to do all kinds of things like that. It just takes time.

BURNETTE: Well the pattern recognition problem, electronic pattern recognition problem, is still a frontier area too. And the real question here is "How dependable is our analysis?" Let's say it's based on multisensor data. I don't think you want to simply impose that on a CRT, you have to analyze it and then give the guy something he can see. That gets rid of the basic problem that we have but that is a very tricky problem still at this point. We have a large handle on the theory for

how you go about it. There's an awful lot of work, I think, still necessary to say that this is something you can put in an engineering development program. Obviously we're ready to start looking at that sort of thing but the probability of detecting a target is a question that, in an operational setting, you're worried about the kill ratio, whether or not you're picking it up or you're seeing all of the targets. The big question I guess that I'd like to address to this group is I've heard some people say "Hey, I've got to be able to see it on the display" and then others view the situation like the Navy. Colombo talked about looking out for 100 miles, and happily, he was doing it with sensors and picking up targets. Now he had an air or atmosphere background there. Now on the ground it's a different story, a lot more noise. It's a question of whether or not he can reliably pick up the target. Certainly that's what we're shooting for but which way are we going to go? Are we going to throw away information we have to make a decision, are we going both ways for a while here? If we're going to go both ways, then we need better displays and better sensors, I think. Now that's a point of discussion, I mean others wouldn't think so maybe.

VERONA: Keith, remember we've got a lot of sources driving displays and some of these have been pretty much directed at target acquisition and possibly weapon delivery. But what about our navigation and pilotage tasks?

FRICK: Navigation still may depend on target acquisition because in order to very precisely navigate a DNE or something like that it assumes that you know beforehand where you are going. So therefore you

have to acquire the target first.

VERONA: Okay, but I guess I'm talking more from the Army's standpoint where you're using your map. It's a map display and you're going between the outside world and your map. You're in a night time environment. You also need a wide FOV, you've got to match the outside world with your map, whether you use a Doppler or another navigation system. You still have to have an outside reference.

HOFFMAN: Bob, I think the questions's fair, and it gets back to the navigation problem. In target acquisition, do you in fact need to see that target or in fact do you generate it via an autocuer? Well it hasn't been implemented, we've been using it for years for short term work. We do a lot of comparisons and go ahead and digitize and do a lot of things to it. The question is, do we need to see a target or do you generate one on the display and say, hey this is what you've got. We've done this against FLIR, we've done it against radar, we've done all the comparisons, we say "yes" you've got a deuce, and put one up. If in fact you're going to use your sensor for target acquisition and also use it to effect the system's navigation where you actually need to see the imagery, it seems fair that you might want to address, do you want to go into this autocuing business and actually put the targets up. It's experience, anytime you start talking about, saying you're going to automate the sensor, that darn processor is going to have a lot of different aspects, a lot of different ways of looking at it and...

VERONA: Bucks go up.

HOFFMAN: That's right, bucks go up. It's very expensive.

SCHLAM: I'd like to go along with that thought. On radar systems we've been doing that for a long time and why can't we do it in electronic systems? In many cases you process the raw radar and put it up on the screen in a very palatable way. You don't always have just blips and there's no reason why we shouldn't do a similar type of thing with our electro-optical sensor systems. The only thing is now you're going to a daytime situation where we don't have radar. In the Army you're in the daytime situation where you want to go for feature extraction and now you're going to use some edge technology and the guy goes dizzy watching it. I think the worse case is the nonmoving target. Maybe the decision making processing should be made by a machine not a man. Look at Air Defense, Air Traffic Control systems; it's all artificial but it tells the guy what he wants to know.

HOFFMAN: I'm saying the system breaks down in the worse case situation, in all cases.

PATNODE: But even if you're moving against a stationary target, you still have motion, it may not be the degree of motion that you normally have in your system.

(Non-transcribable segment.)

MYSING: I think you have to put automation in perspective to the timing of your requirements. I don't think that the state-of-the-art is such that you can release a weapon automatically and anticipate the accuracy for that here. I think we can speculate about that for some time before you have accuracy such that the doctrine will say, "Yeah, you go ahead and release a weapon on that target." It will be an aid to you, yeah,

but let's not try to pass the problem to another group totally.

FRICK: Maybe an analogy would be that you're looking at the whole sky but you're interested in looking at a particular constellation or group of stars. If you could have something to automatically track that telescope on that part of the sky to look at, then start searching, and even then, I don't know why you have to have the exact energy, in all cases, maybe a fascimile would do as far as plotting it.

HAKE: Kind of along that line, you might have a cuer, and perhaps you can't put a cross on the target but maybe you can point out a couple of areas where you can zoom in on it and use that high resolution to present it on the display.

VERONA: For a FLIR you see a high delta T out there, you look at that delta T.

BURNETTE: And then in terms of this thought process, the matter of image quality on the display determines what the actual range for a certain FOV is. That's really what the relationship is. You don't get a proportionately larger range when you get a proportionate increase in image quality, as pointed out by Dr. Snyder yesterday, but you do get an increase and that's what you're really talking about. Suppose I'm at some distance, now given that distance and a certain FOV, what can I see if I look out with my eyes and I have clear visibility. I can see very, very good compared with a head down display. But the question is, "Just how good does that have to be?", assuming that you're going to detect it and identify it on the display.

VERONA: Colonel Patnode.

PATNODE: In the helicopter cockpit, we in the Army, have to sort out between tanks the difference between an M60 and an XM1, a T62 and a T72, etc. And although I have had a lot of tiffs with my guys who are working on this autocueing business, and the characteristics of target signatures associated with a particular target, a lot of that looks very promising and I see support for this sort of thing due to the growth in digital processing. When combatants start using each others equipment on the battlefield, one needs more than target signatures. So I get down to that zero point. Do you have to see the target versus can you take a symbology representation of the target and operate with that. I'm saying guys, that's a tough nut to crack and we ought not to launch into that one too fast because you'll liable to get into an arena where you're going to need optics to get you that detail. The enemy tank operator wouldn't have to be too smart to dope out the intelligence network to see if someone had an edge tracker set up for a T62. He could take a piece of angle iron and weld it to the aft deck running it up at a 30^{o} angle to the turret, where it wouldn't hurt anything. He would change his whole profile and drive those smart Americans with their automatic processing up the wall. If you're going to have something that automated, it ought to be automated and kind of like spook proof. Those kinds of considerations have to be looked at. Can you work with symbology and target engagements or do you have to see something--a real live conventional target? That brings me back to my direct view optics. I don't think any attack helicopter pilot will search in daytime with direct view optics. My belief is he will use the FLIR to find the area of interest and then he will switch to direct view

optics or TV until he gets the best representation. Now, if you want to address another display problem which the other sensors don't have, "how do you autotrack a direct view optics scene."

VERONA: Gil, do you have a solution to that problem?

KUPERMAN: I just wanted to lend some stress on the rules of engagement for any of these systems because you may be able to go with a purely symbolic representation and with an autocuer under some scenarios. In other cases, you've got to have direct, positive visual confirmation and those are orders of magnitude apart in terms of what information has to be brought to the operator.

OHLENBERGER: How would you work in some areas, say like the first echelon where for example, you're much worried about whether you're mixed up with friendly equipment or enemy equipment? Maybe you're able to get by with cuing in this area but when you start working here, like we're working in the Army, the kind of fast moving environment we're talking about, you can very well see you're going to have many, many cases where you're going to be mixed up with American, Soviet, and allied equipment all in the same area and we've got to have positive ID. That's all you need is to be out there with Hellfire missiles and kill your own tank, and you get unfriendly in a hurry...

KUPERMAN: You've got "x" number of seconds to do it.

OHLENBERGER: That's right, so you got to make sure that that is positive. Like the Colonel said, you got the situation there where you have to make sure that you can't be spoofed. Another thing you don't want them to have 5 tanks out there and spoof you with paper profiles and little IR

generators and make you believe they've got a 100 tanks out there either. All you're doing is wasting a Hellfire missile on a piece of cardboard; you can't afford that either. So you've got to be sure. I'm not sure what the answer to that is but I don't think it's putting a symbol on a screen for you and then saying "That's a tank."

SIWECKI: I think both of the guys are right, it just depends on what type of mission you're talking about. If you're talking about a single seat F-16, he's going to need all the help he can get, he may have to have symbology, you know, rather than a raster or whatever. But when you've got two guys in a helicopter, you've got a better chance. There may not be that kind of problem...

OHLENBERGER: Wait a minute. Put yourself in a tank on the ground. You don't care whether it's an F-16 or attack helicopter; if either one of them can kill you we've got something wrong. I don't care if there's only one guy in the cockpit, that doesn't give him the right to go out and kill friendly targets. It's as simple as that.

REISING: Your point goes back to what this gentleman said. If it's an interdiction mission and you're beyond the FEBA, let's say, in the second echelon, he can hit any tank he wants and it won't hurt anybody.

OHLENBERGER: In most cases that's fine.

REISING: But suppose there is support like there is around the FEBA, same as it always is.

HOFFMAN: I think then it's a real question of how much autocuing and all that really gives you in a fast moving environment, pick out a target with the FLIR, get a big blip, and go in. How much is really there?

OHLENBERGER: Now there's another situation related to the second echelon. How many times do you want to kill a tank? You know, the tank is already dead and you don't want to waste more ordnance on him.

FRICK: He may have that problem anyway, even with an autocuer.

OHLENBERGER: Yeah, that's true but what I'm saying is that with technology and that sort of thing, you're going to have to work the problem.

VERONA: Elliott, you have something?

SCHLAM: Yeah. I was working on a proposal and the decision on who to fire it on, in the Patriot system they went to a completely automatic system and the Air Force people objected strongly for the very same reasons. The guy drives for a target, puts a symbol out there and fires on that symbol, but on the other hand you can't deny that if you've got optics you can see it better. When you're up there in a helicopter there has to be some system defined where you use automation wherever you can but not taking the decision away from the operator and make him do something that he doesn't want to do. There has to be a better way.

OHLENBERGER: Okay. And then also, you know, you may be going to the point where you work the pilot out of the cockpit also, if you understand what I'm saying, you've got to watch yourself.

PATNODE: We're getting back to the historical argument about the old autopilot, pilot in the loop versus pilot out of the loop. In a weapon system I think combatant doesn't want to be out of the loop. Our position in the Advanced Attack Helicopter is that you do not want to take the combatant totally out of the loop.

ANONYMOUS: You've got to have some automation but you've got to have that

man making the final decision.

HAKE: Well our problem is, all pilots no matter what service they're in, civilian pilots, whatever, have a certain amount of macho that they perceive with manipulating controls, flying that plane and so forth.

PATNODE: You automate as much as you can of the functions that are supportive of the pilot's decision making process. And then let them put their mind to weapon delivery mode and work that mode. I don't think anyone wants to replace a pilot or a copilot/gunner or a weapons control officer with a microprocessor, when deciding what kind of displays we ought to use. In fact that's a different problem because you don't have a bunch of these other problems as far as working the environment, signal-to-noise ratio, and all that stuff that comes from the ground.

MULLEY: There's an interesting thing going on and we're dealing with this because of the diffraction optics in the HUD. Because of the technology in this area they are putting a FLIR directly on the HUD even during the daytime. I think it's interesting what they've done. They put the FLIR at the bottom half of the screen and they can detect targets, a symbol through the ambient. And not only does he see the FLIR image but he can also look out and see where that target is now. Comparison, now he makes the decision...(rest non-transcribable).

BURNETTE: That tank situation discussed earlier would be greatly enhanced if at long range you are able to put circles around what are tanks and now as you come in, you can start possibly zooming sensors to find out, hey, which one is it that I want to hit. Your zoom capability is fantastic if you know where the potential target is, and only in that case. You've

got to know where you're going to be looking with it.

(Non-transcribable segment by Colonel Ohlenberger.)

VERONA: What about these pilotage-type displays, as far as the new technology that now exists? Has the Air Force requirements for a pilotage system?

WARUSZWESKI: I've got something on pilot safety. We're going into electronic displays, especially HUDs. I think the HUD will be his primary flight instrument of the future. Actually we're already using them as the primary flight instrument in some airplanes. There have been cases where the information on those displays, be it EADI or HUD, or whatever, have been in error and not notified to the pilot. And we may have lost a very expensive airplane in Germany not too long ago due to that case, at least it was cited as one of the reasons. Many of our pilots that are being trained now are being trained to use the HUD as the primary instrument. And out of a pilot survey, I think it was something like 15 pilots out of 30 said they used the HUD as their primary instrument. Another 7 of that 15 said if anything happens in that airplane, the first instrument they look at is the HUD. So I think we ought to be a little more concerned with what they are putting up on the HUD or any electronic display for pilotage of the airplane and make sure that that information is reliable, its been sensed and failure monitored continuously all the way from the sensor to the display. When it does fail, sense it.

WARUSZEWSKI: (First part non-transcribable)...That means that you pull up at a certain angle, roll off at a certain angle, and try to get away from your buddies in the formation. Everybody does that, breakaway. And if the HUD had failed, like we had it fail in flight test one time, the

director information freezes and doesn't tell the pilot that that information has frozen. He'll pull the stick over into a roll, and the HUD says he's still wings level, so he pulls a little more and a little more, until he went into the ground. We never heard a word from him until he broke out of the clouds at about 100 ft. Going at 500 knots there's nothing you can do.

ANONYMOUS: Was it the sensor or...

WARUSZEWSKI: INS failure.

ANONYMOUS: Normally don't you get flagged?

WARUSZEWSKI: No, the ADI should have indicated that it was a failure because we properly monitor that information going there.

ANONYMOUS: But the ADI has a flag on it, he should have seen the flag on it.

WARUSZEWSKI: No, because he's been trained to use the HUD, so they don't look at the ADI, they look at the HUD.

(Non-transcribable.)

WARUSZEWSKI: I know what we need but we're not designing the airplanes that way guys.

PATNODE: You've got a very valid point, having seen the HUDs artificial horizon superimposed on the natural horizon all day, every day, you become very comfortable with that. But you ought to be warned when it isn't doing that.

(Non-transcribable segment.)

VERONA: Okay, we're drifting away from visual displays.

SCHLAM: In a case like this, we can say it's the display's fault but

it's really a system problem.

(Non-transcribable.)

VERONA: We've found that the night vision goggles are being considered as a short term solution to a pilotage display by the Navy and by the Army. Possibly a long term alternative also. We have (END OF TAPE)... the wide FOV in order to get the necessary pilotage information, is that an Air Force problem also? On the '16s, '14s, in the Navy? Are they planning to use any imaging display for pilotage systems?

KAY: I think some of the outputs of our single seat attack program may apply. Just as a mechanization factor, we feel that a 1:1 correspondence of the HUD with the real world, that kind of thing, or you come up with a 20° FOV in order to fly the simulator. We put a lot of pilots in the simulator, flying this way at night, where the only information we're simulating is outside on the terrain board and all he has is the 20° in front of the airplane that he senses with the FLIR. When he turns, he wants to see what he's turning into so what we're doing is giving him a flip mode of 20° where he flips over to the side to make sure that there's no threat there before he makes his turn. That's the biggest we see, the more the man can see (rest non-transcribable)

VERONA: That's why we've got the HMD for use.

ANONYMOUS: You're going to slew a gun around with that HMD also, right?

VERONA: We'll slew them yes. Drive signals are available to the weapon systems as well as to the sensors.

ANONYMOUS: We don't slew our guns around.

VERONA: Your guns are locked though.

VOICES: Slew the airplane.

KING: I guess one thing we've found with the Navy and Marines and Coast Guard is once you do have a FLIR system and your display devices, etc., the pilot and the other people in the cockpit that are there are perhaps going to use it as much as possible. We certainly want our prime looks to be at take off and landing off of ships or other areas. Formation flight, we've been looking at, hover, hovering in transition for V/STOL or helicopter aircraft. Hovering and picking up cargo, using it for rescue, and even using it for reconnaissance.

VERONA: You're talking wide FOVs. We're talking, the Army's talking about a 45^0 FOV. You mentioned 20^0 FOV.

(Non-transcribable segment.)

KAY: We found 20^0 because of the airspeed for the A-10. The F-16 now, through the same sort of concept used for the A-10 is like 12^0. All he has is 12^0 beside the aircraft because with the turn rates at the required speed he doesn't need more than that. If we can give him just 12^0 beside the airplane he's got everything he can take advantage of, react on.

VERONA: What about your case, what size are you using?

PATNODE: It isn't what size because once they have it in the plane, they're going to use it for a lot of other modes than just say, weapon delivery or target acquisition.

VERONA: Okay, but if you have a $3/4^0$ or 2^0 system, that's going to be a lot more difficult to use. It may be possible for some of these if you have a wide FOV system. And the technology problem really gets difficult as you start getting out to the wide FOVs and also want high resolution

because you're dividing those resolution elements up by a large amount.

ANONYMOUS: I think the Navy on the helicopter program at least would like to design it to 60^0.

ANONYMOUS: Yes we would actually desire a lot more but 60^0 is something that might be attainable. 180^0 doesn't seem attainable before the year 2000. These are our desires for where we think we are going to get some use of technologies coming up in the near future.

ANONYMOUS: I was trying to indicate that, for at least helicopter's, they have come up with wide FOVs more positive than what the Army would like to have also.

ANONYMOUS: We're mimicking the Army as much as possible.

BURNETTE: Could I get clarification here. Are we talking about using video as a situation-type information thing now, where orientation...

BRINDLE: We're talking about using video as the only source of visual information to the guy flying the airplane.

BURNETTE: So in this case it's not to detect targets, its simply for orientation, where you are and all that stuff. Could I ask, maybe, what is your assessment of comparing this with past contact analog. You know, it seems like it's related to that, which is effective generated representations of the real world in comparison to an essentially relatively low resolution. The guy is not focused, he's got a large FOV, you know, normally about 20^0.

KING: You have to remember now, I'm from the acquisition area and cost becomes a prime concern. And we do processing of a lot of information, in the ASW area for instance, a lot of detailed, signal-type information

coming in and is processed by very, very expensive processors and then presented in symbolic form for the ASW problem. I don't think that you can do that on every helicopter. We're getting into almost million dollar helicopters for ASW.

BURNETTE: No, I just wanted to know if there was any known information, since you're not now dealing with a target detection signature as far as high resolution, which way is best to go? Something that gives you terrain features for actual terrain?

KING: Okay. The F-14, F-18 now, where you do have sensor information, detailed radar-type information, air-to-ground or air-to-air, primarily we put the information up in symbolic form. If the pilot wants to take a more detailed look, he has the raw data information coming in or semi-processed.

MULLEY: That's the only one that I know of. I've got to stick to my own gut feeling that sensors available to deal with that kind of information have never been designed. Everybody thought they would be.

GURMAN: There may be somebody here that goes back farther in contact analog than I do but I'm not sure anymore. (Non-transcribable)... That's an IFR system. It is not a tactical system. You can't use it in a tactical environment. It requires sensors which I don't think were appropriate for this. You have your manual Nav sensors, intertial systems, it's essentially an IFR system. And I think we're talking about something totally different here, we're not talking about IFR.

ANONYMOUS: We probably should be involved in it.

GURMAN: Not really.

ANONYMOUS: Aren't missions defined in terms...

GURMAN: Not in terms of IFR. You're talking about a different kind of regime. You may be flying IFR during part of your mission but the mission is not an IFR mission.

MULLEY: What about terrain following... (rest non-transcribable).

GURMAN: Who's doing terrain following?

BURNETTE: I know the Avionics Lab has this program on contour maps, three dimensional contour maps, graphics.

VERONA: Colonel Patnode, you said you had a couple more questions before you had to leave.

PATNODE: Is LT Mitchell here? You said an MTBF of 300 hours and you are using common modules.

(Non-transcribable segment between Col Patnode and Lt Mitchell concerning the question of MTBF.)

VERONA: Sir, are you saying that 300 hours is a conservative figure or is...

PATNODE: No, optimistic.

VERONA: ...a very optimistic figure.

PATNODE: Optimistic when you use common modules. You can't have your cake and eat it too. You can standardize our common modules but I think there will be a second generation of these modules. I personally think that the two areas of the common modules that probably will give the most problems are the detectors and the pumps.

VERONA: Sir, did you have something else?

PATNODE: Okay, I did have one other question here. Is Mr. Colombo here?

VOICE: No.

PATNODE: He answered one of my questions yesterday about the management of the mux system which I think is something that all display guys ought to be interested in to some degree. The central computer or fire control computer, whatever you're using normally, does the management of the mux, and then most systems have a backup mux control somewhere. And my specific question today, and I don't know if you can answer it is, "What percent of your functions do you drop off before you use your mux backup?"

KING: What they're prophesizing in the F-14 CILOP is, you have the central computer which does mainly weapon's computation, aircraft monitoring; that's the AWAC 814. You also have computers and processors for the displays, wind inertial system, etc. All the avionic subsystems have this processing capability. The advantage of that capability added to each one of these individual processors is for the executive programs. So each one of these program processors could have that takeover capability, sort of a serial routine where each one checks on what the last computer did below the mux bus. Did it do everything okay? Okay, proceed. If it didn't, the executive program takes over and gives the order to the next processor, saying I did the executive program go ahead and do your thing. It's an idealized concept. We haven't done it yet but it's for an ideal situation at best.

(Non-transcribable segment.)

PATNODE: It goes beyond the executive though, somewhere in your backup you've got to have something (non-transcribable)...it's really the primary system. As you go to the secondary and tertiary mode of operation, what you're saying, I guess, is that you are retaining all of the

capabilities that you had in your primary mode of operation.

KING: Okay, I can give you an example.

(Non-transcribable discussion.)

PATNODE: You take over the management of the mux and how much more can that manager do as far as the weapons, the sensors, and so forth?

KING: Let's take an example. Say each box has its own percentage of the executive in it, let's say in the display processor, it's there waiting to take over that particular area, curtaining off the other processors. Let's say there's a failure in the display processor. We have two processors, in other words, to drive all the displays plus the backups; if one of them fails, we expect to have an 80% capability providing all the information were optimal at one time to the operator. We can provide all of the information to the operator except it will be a lot slower, not a lot, but slower. This is in essence a soft type of failing of that vital type of information to the pilot or all information to the pilot whether it's vital or not.

(Non-transcribable discussion.)

BURNETTE: Is the Navy's flight control system something like the Air Force's? With quadruply redundant-type things, control systems, etc.

KING: I think that's what they are proposing on F-14 CILOP, yes.

VERONA: Okay, as an aside, we've got one other statement that was made yesterday and this was concerning accelerated research and development. Can we accelerate R&D for military aircraft just by putting in more dollars. I'm sure we've been caught up in the situation before, trying to do things in parallel that we should have done in series, requiring the output of

one program to drive another. Jim Brindle had an old expression, "Can nine women have a baby in one month?" and I think that we have been put in that situation before. What are the practical time frames for these advanced displays?

SCHLAM: The answer is a definite maybe. It depends on what you want to do. I don't think we still know where we are. We've been toying with ideas, you know, you've spent lots of money to build all kinds of display devices and we spend more money looking at more systems integration in finding out the best way to use the technology that we think we have now or we'll have in the next one, two, or three years. You want to spend more money, I think, for systems integration. The thing we discussed yesterday was, you don't want to put 6.3 systems in a thing that you are being graded on.

GURMAN: I'd like to say something similar to what Elliott just said but in a different way. The topic of this morning's meeting is "to determine how the topics covered in the first three sessions interrelate or what impact each has on the other and then, obviously resulting in advanced display requirements." The objectives of the three sessions were "to provide attendees with insight, in one case, on doctrine and mission requirements and identify what the requirements are." I'm not sure I know what the requirements are. "To acquaint attendees with the process that the system engineer uses." I think we've gotten a flavor of that, though I'm not sure I really know although I've dealt with it before myself. "To delineate the vision human factors, performance factors." I think we got insight into that. But I can't say, if I were to be in the position

of advancing the development of display technology, just what the requirement of that display was in terms of the information nor what the system effects of the system integration complexities are going to be, how they are going to affect the display, or in terms of the human factor performance characteristics, how in fact they affect the display development. I think we, and I refer to an earlier meeting of a tri-service display group, have been hard put to try to describe what's been done, what's being done, and in a sense, what should be done over the next five years in falt panel displays. I think we can describe relatively well where the technology is and how it's developing and I think we can probably provide insight into how we can quicken that development. But if the question now is, "How do we do that with respect to the night vision requirement?", I'm not sure I yet know what that night vision requirement is. What is it that we're trying to do? If it's pilotage, that's one thing. If we're talking about adding the factors of discerning targets or separating them from ours, etc., that creates a whole other set of characteristics which I don't fully understand yet as far as how they are going to be translated into display requirements.

VERONA: And that's been one of our problems because as it has been mentioned several times, it's the technology driving the requirements rather than the requirements driving the technology. You can't split them off completely, you've got to talk to one another.

GURMAN: No, it's a reiterative process and I think that's why we tried to call this meeting. (A) to start communicating and (B) hopefully to try to give you more detail, we hope, what it is we're each trying to

do and how we can get there together.

VERONA: Then something like this (pointing to blackboard) is a reasonable breakout.

GURMAN: Not enough. I think pilotage, whether you're talking visual or TV or FLIR or something like that, is generally the same, there are different specifics. But, if you add to that, target acquisition, and more than target acquisition, differentiation, and then weapon delivery, if you so decide, I don't know yet how that translates into the display descriptions.

VERONA: I don't think it has been done very well so far.

GURMAN: We have to have that.

PATNODE: We cannot write a detailed specification for PNVS. Our PNVS, in fact, as you probably know, is very subjective and qualitatively described.

GURMAN: I appreciate that. I think what I'd like to see, although it's optimistic and I'll probably never see it, is the requirements people saying "I have certain things that I have to do out there on my mission. I have to separate a tank from a truck, one of theirs from one of ours, find out whether it's been shot before or is this the first time, that type of thing.

VERONA: At what range?

GURMAN: ...at what range, under what atmospheric conditions, under what altitudes, at what speeds. Now when we can describe that, go on to the next step, not necessarily accurate, you're not making it definitively,

just ball park the next cut at it. Which is, how do we treat that in terms of the sensor? Do we have sensors that can do some of those things? What has to be done to the sensor? And how do we get this into the system context and what information must be provided to the pilot in order for him to make these decisions? I don't think we should be equipment designers here nor should we be sensor designers here nor display designers here. I think I've heard somewhat of that today and I don't think philosophy is the most important thing. I think that if we can start to define these things with the idea that the system continually reiterates and as we get to know them better, we get the systems, documented and start flying them so that maybe you can make the decision up to two out of three, if that's what you decide, then we can get some of the answers and feed it back into the loop and get better ways to describe these systems.

PATNODE: All right, I'll take five minutes on that blackboard and show my approach to you, you can question me about it, if it's of general interest to everyone.

VOICES: I think so, yes.

PATNODE: Part of the problem we're talking about manifests itself in the training problem. When we laid out the Advanced Attack Helicopter program we did not put enough time in the development phase to have enough blade hours to properly train the copilot/gunner and the pilot. An additional problem was that we knew that we just didn't have a large resident population of pilots that had flown FLIR-type PNVSs. We're growing in numbers of guys who can fly the goggles well. So we were faced with a couple of

problems. Extending the development program to get the blade time on the 64 for training is a very expensive proposition considering the dollars involved in a major weapon systems development. There's got to be an easier way to do it. So we got a Dedicated Training and Test Detachment and this outfit is forming up at Yuma right now. The way I approached this thing was we have to train pilots and we've got to train copilot/gunners to be able to fly these systems . . . fly these systems around the trees at night, learn the process here and therefore, instead of flying 25 hours in the AH-64 to do that, we must be able to do that in 5 hours in the AH-64 after leaving the surrogate training system. The pilot is transitioning from one airplane to another but he's using the same PNVS. Now in addition to that, you always have a crew coordination problem and I'm so old fashioned as I mentioned yesterday, I like the side-by-side arrangement as the Navy uses in the A-6 and not this tandem stuff; but we've got two AH-1Ss with a TOW weapon system as part of our Dedication Training Detachment. These systems have as their primary use the TOW sighting system and we're going to use that to train the copilot/gunner in direct view optics. We're also going to use those two birds for crew coordination training. Over here, on the copilot/gunner side we've got two ATAFCS systems installed on AH-1Gs. We've done some upgrading with the HELLFIRE PM. Understand we're integrating with the HELLFIRE PM because he needs four of these ATAFCS birds to do his own thing. We need two for target training, we need two for development of his missile system. So we've decided to fund two and he funds two and we ship them back and forth because we're all at Yuma anyway. These ATAFCS trainers

have a FLIR and TV autotracking, laser, but they do not have direct view optics. Now this outfit which was intentionally named the Dedicated Training and Test Detachment has the guys who do the instruction but will not be the subject pilots for DT or OT. They will train the subject pilots for the DT/OT. They will also train the Hughes contractor pilots in the use of these systems. The Hughes pilots don't have the proper background on these systems either. So that's the layout.

Now to get more specifically back to your question. It is my hope and the hope of NV&EOL, that the life history of these systems will provide us a vehicle to better define the specs for PNVSs. Due to the funding constraints we didn't instrument these birds to the degree that NV&EOL wanted them instrumented so that they could get a handle on writing a more detailed spec for a PNVS. But I do believe we've taken the first step here to be able to work that problem because over a four-year period they have high training requirements over relatively short periods of time, and they have refresher training requirements. There will be some time for NV&EOL to use these trainers. Because it's been our experience in all the work that we have done at CDEC and NV&EOL that guys proficiency in flying these night vision systems degrades very rapidly and Air Force has found this in PAVE TACK. They can't go 25 days without flying the system without having a significantly reduced capability. So here's a refresher training requirement out here. We're not trying to get the answer on TADS because there are a lot of specifications on the TADS system. The ATAFCS trainers give the guys some fundamental practice in manual tracking, autotracking, target designation and so forth. Now in the world that we like to talk

about that is not funded properly, there is a gap between basic research guys and those like me who are developing systems. There used to be a lot of test bed vehicles like this in all the services. I used to work with the Navy and the Air Force on the VTOL prototype airplanes like the fan and wing and ducted props. To get back to one of my bottom lines, why should I, as a Program Manager, pay for these test bed systems when they should be resident in 6.3 type systems and I could use and only pay for the hours I use it. Now I do have one other vehicle that I control that belongs to NV&EOL, that's the LOTADS bird, an OH-6 with a PNVS and designator system on it. The LOHTADS bird sits in the NV&EOL hangar but I control the system. I'm trying to get a poor man's 6.3 system for the Army but selling this to the R&D guys in Washington, the ones you get your money from, is a tough nut. They don't recognize it because most of them today have never spent time in the labs and the places like you've spent and they don't understand the problem. They think you can do it on paper.

GURMAN: This is another cut that I would like to get at and that is, once you've done this training program, seems to me your training program is also a test program. Because it's going to tell you what you can do with the system and what you can't do with the system. And then, seems to me, you can look back at the requirements for these sensors you've defined. Seems to me they're going to be redefined based on what you do, but I'm not quite sure of that. If the intent of that hoped-for requirement had been met and to the extent that the hoped-for requirement is known then the question, "Do the requirements have to change to meet the limits of the system or the limits of what you can do before you can

improve the system?" Okay, this is really saying, reiteratively you're going back and getting a better handle on the requirements, to the extent that they can be met and to the extent that they're really necessary. You know, this is what I was really getting at, if the requirements are to differentiate between one of theirs and one of ours, that's so much greater than differentiating between a tank and a truck and a man or a jeep. And if it is, let's say, close to the FEBA and then if that's really the requirement, then the question is "Can we meet that?" And if we can't meet that, is that a realistic requirement? It seems to me it works both ways. Then that impacts on whatever you do with the rest of the system. The sensor requirement is greater, I don't know how you define this. Generate sensor requirements and maybe the display requirements go along with it. They have to match, the system has to match. We have to have all the pieces to be able to reiterate. I think what you're doing is a good exercise and maybe that will help redefine the requirements, qualify the requirements, make them more or less realistic.

PATNODE: Let's take the first part, the PNVS thing as an example. Within the NV&EOL community they say, from a pilot workload point of view, you ought to have autohover. Now, and at the time they were structuring the AAH program, the money guys chopped the shopping list, and we never got the autohover. So the PM said "no" at the time for a number of reasons. Money, schedule and so forth. Well my Dedicated Training Detachment has a tendency to provide an opportunity to say again, "Well this thing works pretty good but we need autohover." Now onto the targeting thing, I don't see how we can get away from this because every display guy eventually will

give you the imagery that you see through the sensor or the seeker if you want it. But you know we have a fundamental problem right now because the TADS under my area and the seeker under the HELLFIRE PM area, are in two different commodity commands. This happens throughout the services. So it's very easy for my buddy, Bob Feist, who is the HELLFIRE PM, to take his seeker problems and redefine the requirements for the designator. This goes on quite often. Because we don't have these total systems approaches across the total weapon system in the AAH, I personally think the HELLFIRE should be under the AAH. If I'm working for BG Browne the HELLFIRE guy ought to be working for BG Browne. But that's the way the world is. I didn't make it, I just live here. So the problem in the display area, the part we haven't talked much about here, is also over here in the seeker area and the auto-correlation area also. A fundamental problem is the handoff of an I^2R between the real imagery you have over here, which is a pretty spiffy system compared to the sensitivity of this one, and how you can very cleanly make the transfer in auto handoff from the sensor such as the FLIR sensor in the TADS, to the seeker of the missile system. Now, if you've got a lousy FLIR over here and a relatively lousy FLIR over here, the problem is a relatively simple one. But if you've got a spiffy kind of resolution over here and on the one here the resolution is flaky then the correlation in the auto handoff is going to be a problem. I don't know what the guys in the seeker business and the processing business can do to simply this. They are working very hard on it right now. But I'll tell you as far as TADS goes until we build some systems and not only get operational experience but do some very structured field experiments we're not going to be able to

write this. Now it's not all bad because LDWSS, the laser designation weapon system simulation, is super in doing the analytical tradeoffs between the two sides of the house. Now I don't know if my total pointing and tracking accuracy is achievable. You know, the stabilization people in the Air Force and the Navy and the Army all kind of scratch their heads and say, "Well, maybe if you're lucky."

SCHLAM: Colonel, I'd like to reemphasize your point about this 6.3 business. My organization basically lives on 6.2 electronics money and we have finally recognized it's not good enough to build 6.2 devices because people like you really can't, to do your job right, you can't handle that. You have to have the testing, the additional capabilities to make sure that they can go into the higher levels to do the job that needs to be done. And recently we've been making appeals for so called 6.3A funding throughout the MIRADCOM community to approach doing this kind of job of testing and specifying, etc. The answers we've got back, I think based on Congressional-level decision, is that 6.3A money is not the money to be spent, it should be 6.3B. Which means, how does the PM do it? And you can't, you're not equipped to do it. I think this is a major gap, a major problem, and if we have some recommendations as a result of this workshop, I think one of those recommendations should involve a new area of funding for efforts which we can't do in our present status and neither can you.

PATNODE: In the obscurant program that I mentioned yesterday I have the AAH and HELLFIRE programs combined for this effort. I have 36 DoD agencies in my wiring diagram for the obscurant testing. This is the minimum number

required to do the job. As a program manager for a little 24-inch ball sitting on the front of a helicopter it's incomprehensible to me that no one would do this job for me. Now the system won't provide that so I went to BG(P) Ragano, the MIRADCOM Commander, and said I need help. He is taking over the obscurant testing as the Commander of the commodity command that has a functional responsibility for these things. We're making that transition right now where he is going to set up the obscurant testing arena and then I will eventually be a customer rather than a manager. If we can make that transition in the next five to six months, then there will be a precedent for funding in the 6.3 area, those sorts of things that PMs need to have done.

HAKE: I'm Captain Hake by the way, from the Air Force Avionics Laboratory and we are developing the next gen FLIR. Primarily, what we are trying to do, the question we're trying to answer, and we need some help from the requirements guys and the displays people, is "Can you read that?" (Points to blackboard.) First of all we had some contracts with Hughes and Rockwell. We're trying to increase the state-of-the-art in sensors, the next gen FLIR area. We did some mission analysis work to determine some requirements for the next gen FLIR with some help from XR. As I see it, we've got the sensor design to give us the better performance we need to perform the mission. We had requirements generated and we got designs for a sensor to get better performance than the common module FLIR. The big question we have is "Do we have displays that will use that better sensor performance?" You've got some sort of processor and you may need that because you have operator limitations too that I don't understand.

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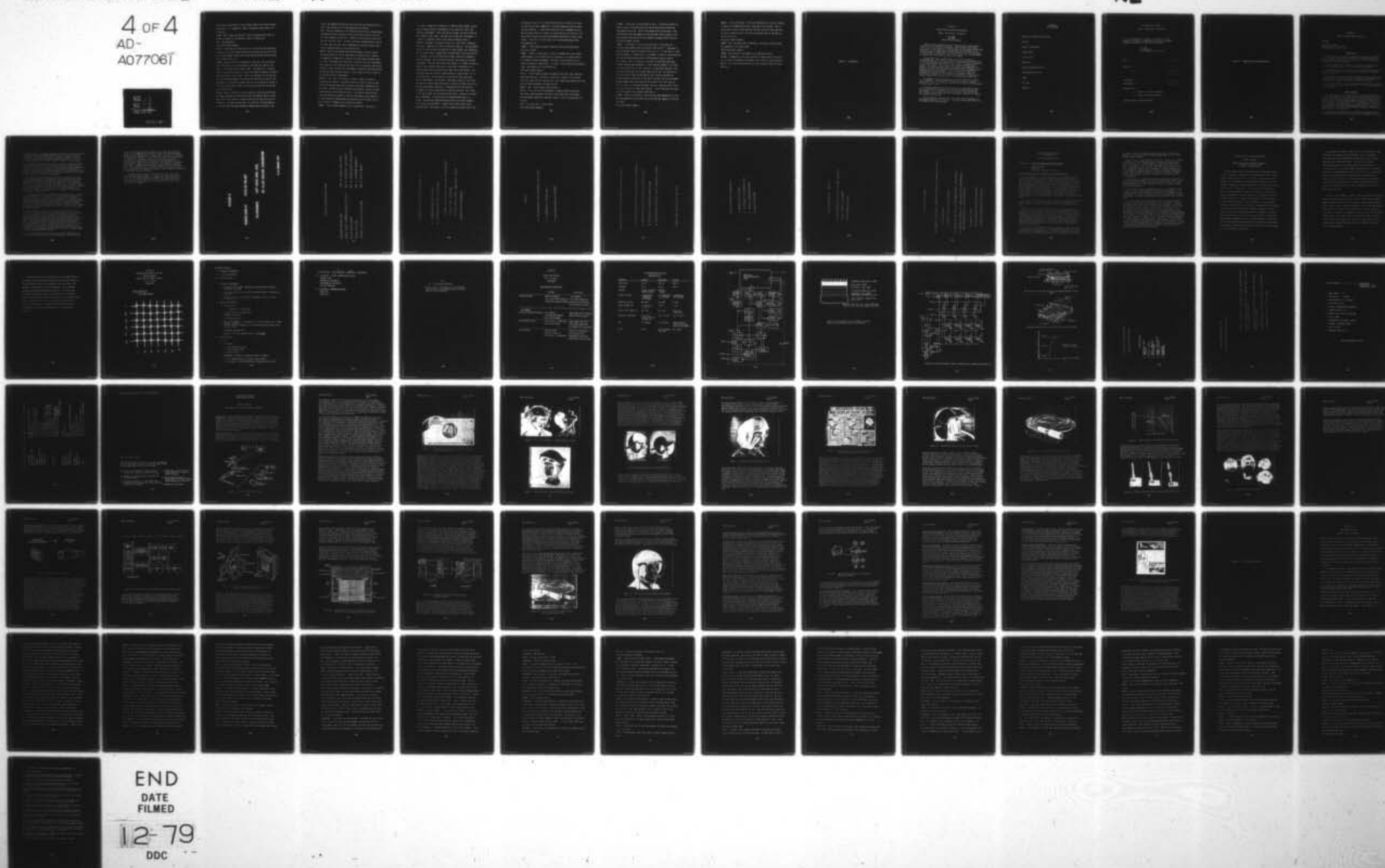

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We may have a super sensor, but the display might not be able to handle that, even if it's compatible. What's the operator doing, what's his limitations?

GURMAN: What I keep hearing here is that the displays may or may not be able to handle it; the question I have is "handle what?"

HAKE: The performance.

(Non-transcribable segment.)

SCHLAM: I think what you ought to do is put a big fat line around that processor box, as we've been discussing all morning, and try to tie that whole thing together rather than putting question marks over the display or the operator and so on.

GURMAN: There are limits on the operator, there are limits of the display, there are limits of the processor, and there are limits of the sensor. I think we can all agree on that. The question is, if you're going to do a mission analysis, it has to be done with respect to doing a particular task or set of tasks. And if you reiterate this so that you can describe the parameter of the inputs and the outputs of each of the subsystems in a reiterative system, then you can say whether a display is available or which one you want to choose that can best do the job that you're trying to do.

BRINDLE: Brad, it might not be only a question of defining the display performance parameters but defining the display modality which he (Capt Hake) hasn't had a chance to, based on what mission they are trying to accomplish. You know, you may have 3 or 4 options of display modality, all of which have the same performance commensurate with those of the

sensor, but depending on what you're trying to do and how many guys you have in the cockpit to do it, the answer may be different.

HAKE: From our standpoint, we're looking at recce/strike, reconnaissance and weapons delivery, and we're looking at the next, aircraft that will be in the inventory in the '80's. Primarily, we're going to single seat aircraft in the Air Force. So that's the type of background we've got up till now. But right now I don't understand all the human factors stuff, I don't understand what all the limitations are.

MARTIN: Dave, let me perhaps rephrase Brad Gurman's previous remarks. The mission analysis, mission requirements information that in general is produced as a community, to date has not really been followed through on. That is, we define what the global, qualitative mission requirements are but we don't ever take that next step, that is, doing the quantitative analysis on that, on that basic requirements information that defines what the sensor/display and man, taken as a total system, must do in order to satsify those mission requirements.

BURNETTE: Yes. And I think really, the way it ought to be done is through mission analysis. We need to define just exactly what you need to do this thing and then start looking at each aspect considering each has limits. And the one we're farthest from reaching is going to be the limiting factor at this particular point. But then at least you know in the end where you're going. It may be 1995 before you get there but at least you have it defined what your objectives are and what, even in your 6.2 and 6.1 programs, you're trying to achieve.

GURMAN: I think I would suggest to you a further step. And that is,

if in fact it comes out to 1995 and it's 1985 you want to meet, you may have to change the basic requirements in the sense that, that's the realistic requirement. That's the one we can meet, not the one that we would ideally like to meet. And then plan to meet that requirement, if in fact it's necessary, ASAP if the system technology allows it.

BURNETTE: Obviously. But what I'm saying is, that's what's happening right now. There are all kinds of voices that come out. My own personal feeling is that the human can make use of higher update rate information, that is, he can look at imagery that's moving faster on the display than he is getting. He can also make use of higher resolution information than he's getting. He can use more lines per inch and he can use more information. That says that a particular target, if it takes 10 lines to define it on a display we have now; it may take 15 to define it on a smaller display but you've got a much larger FOV on that display. His thing says, how big a FOV do I need and what do I have to see? It's a relationship box. How far away do I have to be to see a particular target? What would I like to have? That human is going to limit that. Now there are interim steps we're going to be able to take on our way to that but the problem I have now is I keep getting told "We're there." The human can't use any more than he's getting right now. And if that is true, we're done, we're limited but we're done. We have to live with those limitations. It would be nice to determine which way it is.

SCHLAM: The question asked before which really hasn't been answered, "Can we use accelerated R&D?" I would like to take a quick cut at answering that. That answer is "sure" but what do you want to do it on.

And the way I see it, I've listed three priorities, in priority of what you want to do in R&D. Number one is systems integration and real world simulation studies. I think we're pretty much all in agreement on this. And the second, which is a subset, of course might be test vehicles, 6.3A type of work to get me to the actual hardware evaluation of these system studies. And finally the third would be in display technology device development per se.

VERONA: I think there are some of these test vehicles hiding around, we've got a couple.

GURMAN: I think, in some cases, Elliott's 6.3A model has to be slightly changed because if he's working with a 6.2 device, it's a device that is not necessarily even a breadboard. And what I think we have to do in terms of evaluating these things, is to get it into at least the brassboard stage. Which means he's further than 6.3A.

(Non-transcribable segment.)

MYSING: I think though, we made an assumption here that I don't know has been established yet. And that is, we can put a display in an aircraft which can, under typical situations let's say, supply more resolution in that aircraft than the operator can possibly use...

MARTIN: John, I would submit that we haven't...

MYSING: (First part non-transcribable)...program indicates that given the typical space available, the size of the display that is available, and the dynamic range that's required, there's a lot of displays that can be used.

VOICE: You can't use a 17 inch display.

(Non-transcribable segment.)

PATNODE: I think this is the business of both. I think we've gotten to where at least in the TADS area, with the new AH-64 we can define the requirements end to end. One of the problems we're asking about is can we then define the requirements of the subsystems clearly enough so that people working that portion of the system can accomplish their job with the help of people like you.

GURMAN: I think what I'm trying to provoke here is that there are questions asked whether there are displays that can do it. Some people question whether there are displays that can do it. I think there is some question whether, if there really is a problem, in terms of finding displays that can be used because we haven't defined exactly what we need on that display. Now, if I may ask, do we have to accelerate technology in order to meet some contingency? I don't know yet whether I'm limited to display availability or not. And it's so interlocked that what I was trying to provoke was, yes we have numbers we can use. At least we can set a first cut in motion, draw them up, see if we can describe the system, and then on the basis of the details we need, and the environment, and the viewer, under the conditions he's going to fly, see if we can do it or not do it, and where the weak links are. We go out then, little by little, continuing to move the system up. I don't know what that basic first cut system is yet, nobody's described it.

PATNODE: The guys are trying to figure out what the compromises are from the requirements which have been laid on the Army R&D community on the ASH helicopter

(Non-transcribable segment.)

GURMAN: I think the Colonel is doing an admirable job in trying to develop a system to do something that hasn't been really well defined. Now, it may be that it hasn't really been well defined, but we've never been able to build a system to give us the kind of data back that can say what we can do or can't do.

(Non-transcribable segment.)

GURMAN: Well, we always have to compromise. But we don't know yet what the compromise is for that system.

(Non-transcribable segment.)

GURMAN: And the block of equipment is not questioned as well.

PATNODE: Fundamentally, why should we knock it when we don't know how to cut up the pie, performance requirements wise, within our specifications.

MULLEY: You're doing the whole job, you really shouldn't have to do the whole job.

SESSION V - TERMINOLOGY

Session V

Electro-Optical Sensors and Displays:

Terms, Definitions, Procedures

H.L. Task
AMRL/HEA
Wright-Patterson AFB OH

There are many parameters that are typically used to describe the capability of E-O sensors and displays. Unfortunately, there seems to be a lack of uniformity in the definitions and procedures for measuring the values of these parameters. The objective of this session is to establish lines of communication between individuals who are interested in establishing a standardized set of terms, definitions, and measurement procedures for quantifying E-O sensors and displays.

The approach that is proposed here, is to solicit lists of recommended terms, definitions, and detailed measurement procedures from interested individuals and organizations. From these lists, a preliminary set of terms and definitions will be produced and disseminated for comments and changes. Once a final list of terms and definitions is agreed to, then detailed measurement procedures can be formulated. It is probable that more than one measurement procedure will be submitted for measuring a particular parameter. If such is the case, then it is proposed that each acceptable procedure be included as a means of measuring that parameter. Then whenever that parameter is specified or stated, the specific procedure used or required should be indicated.

For example, there are several ways in which the MTF of a display can be "measured". These different methods do not always yield the same results, thus the procedure used should be stated (e.g. MTF Procedure 1 or MTF Procedure 2 etc.).

The final selection of terms, definitions, and detailed procedures will be published as a reference and guide for specifying E-O sensors and displays. It is hoped that there will be sufficient interest and participation from the three services, and perhaps, industry, to complete this reference before 1980.

The following is a partial list of terms for which definitions and measurement procedures are solicited. Your participation and interest are encouraged and certainly welcomed!

Partial
List of Terms

Modulation Transfer Function (MTF)

Contrast

Signal to Noise Ratio

Dynamic Range

Contrast Ratio

Resolution

Contrast Transfer Function

Video Transfer Function

Gamma

Spot Size

Bandwidth

E-O SENSORS AND DISPLAYS

TERMS, DEFINITIONS, PROCEDURES

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SESSION VI - SENSOR/DISPLAY STATE-OF-THE-ART

SESSION VI

STATE-OF-THE-ART SENSOR TECHNOLOGY

CHAIRMAN

Capt David S. Hake
Air Force Avionics Laboratory
Wright-Patterson AFB, OH 45433

INTRODUCTION

The first part of this session contains presentations on state-of-the-art Forward Looking Infrared (FLIR) sensor technology which will serve to acquaint attendees of this workshop with FLIR technology and its impact on display requirements.

The first paper, by Mr. Siwecki, will discuss the Common Module FLIR technology as applied to the Air Force Pave Tack system.

Mr. Grandjean will present a paper on FLIR Technology Demonstration, the Air Force Next Generation FLIR program for advanced tactical and strategic aircraft.

Mr. Layman will present a paper on the Advanced Tactical (ATAC) FLIR and High Sensitivity Tank FLIR (HISTAF) programs. These are Army Next Generation FLIR programs for airborne and ground applications.

Mr. Hess will present a paper highlighting the Navy Hybrid Array for ATAC (HYTAC) FLIR and Charge Injection Device (CID) FLIR Technology Demonstration programs.

SENSOR OVERVIEW

The current generation of airborne forward looking infrared (FLIR) sensors is represented by the Common Nodule FLIR technology, widely used in Army, Navy, and Air Force applications. This technology provides a day/night, limited adverse weather capability needed in today's battlefield scenarios. The Common Module FLIR's performance is proven, and its use increases the effectiveness of our weapon systems. It provides the advantage of detecting and attacking enemy forces at sufficient stand-off range to perform the mission effectively while increasing the survivability of our own forces.

Unfortunately, scenarios for the 1980s grow more demanding as our adversaries' offensive and defensive capabilities increase. More lethal

defenses will force our weapons systems to operate at lower altitudes and/or at greater stand-off ranges than at present. Provided that their performance can be improved, FLIRs will be very important in these scenarios because they can provide the capability to detect, recognize, and attack enemy forces at night, in adverse weather, at long ranges.

An additional constraint is a result of the new airborne and ground weapons platforms for the 1980's scenarios that are now entering the inventory. The Air Force and Navy will have smaller, higher performance, single-seat aircraft. The Army will get advanced helicopters and ground vehicles. These new weapons systems will incorporate FLIR sensors and will, themselves, influence the FLIR sensors primarily through size, weight, power, and reliability requirements.

Thus, beyond the current Common Module FLIR technology, scenarios and new weapons systems technology trends are driving FLIR requirements toward (1) greater detection/recognition ranges for longer stand-off engagements; (2) better adverse weather capability for locating enemy forces in poor weather, smoke, and battlefield dust; (3) reduced operator workload since the trend is toward more complex weapons systems operating with shorter timelines in the 1980s; and (4) decreased sensor size, weight, power to meet the constraints of new weapons platforms, where performance otherwise suffers.

The approach being used to satisfy these requirements is to increase sensor performance, i.e., longer detection ranges, by increasing the number of detectors in the FLIR and to decrease operator workload by providing automatic operation of the FLIR functions, such as gain. level, focus, and tracking. Automatic target cueing will also reduce operator workload by automatically cueing the operator to targets of interest, hence, reducing the search workload. In addition, various types of image enhancement will provide a better picture to the operator to help make his workload lighter.

The developmental impact of this approach falls into three main categories. First, high density focal plane arrays (FPAs) are required for the next generation FLIRs to provide the high resolution and sensitivity required in these scenarios. These FPAs use integrated circuit technology for target detecting and signal processing. Several FPA approaches are being pursued which could provide these required arrays. Second, the new FLIR technology approaches all basically utilize a standard 875 line TV format, producing 875 lines of IR video from the sensor and requiring 875 display lines for presenting the information to the operator. Finally, autoprocessors will be required if the new FLIRs are to handle the automatic operation. automatic target cueing and image enhancement features.

With these FLIR trends in mind, there are several display issues which are being addressed by the sensor developers. The first is the

need to ensure sensor/display compatibility so that the display can handle the increased sensor resolution, sensitivity, MTF, and dynamic range which will be available. Second, there is the need to optimize the man-machine interface so as to maximize sensor information transfer to the operator. Finally, the need to provide adequate display performance for the operator within the constraints imposed by the weapons system, itself, must be addressed. Very limited cockpit space is available for displays which severely limits permissible display size. This, coupled with long display viewing distances, effectively limits the system resolution. Displays must also be capable of functioning under both very high and low ambient light conditions encountered in day/night tactical environments.

In summary, we have seen how future scenarios are driving FLIR performance requirements higher. To meet these operational requirements, next generation FLIRs, incorporating focal plane arrays and autoprocessors, are being developed by the Army, Navy, and Air Force. The following presentations will provide more detail on these next generation FLIR programs.

SESSION VI

SENSOR/DISPLAY STATE-OF-THE-ART

CO-CHAIRMEN: CAPT DAVID HAKE, AFAL

DR. ELLIOT SCHLAM, USAERADCOM

16-18 JANUARY 1979

SENSOR PRESENTATIONS

SENSOR OVERVIEW	CAPT D. HAKE, AFAL/RWI
PAVE TACK-COMMON MODULE FLIR	MR. R. SIWECKI, ASD/AER
FLIR TECH DEMO	MR. A. GRANDJEAN, AFAL/RWI
ATAC, HISTAF	MR. S. LAYMAN, NV&EOL
HYTAC, CID FLIR TECH DEMO	MR. M. HESS, NADC

CURRENT FLIR SENSOR TECHNOLOGY

- O COMMON MODULAR FLIRS
- O TRI-SERVICE APPLICATIONS
  - O ARMY - TTS, TOW SIGHT, AAH (TADS-PNVS)
  - O NAVY - P-3C, A-7E, A-18
  - O AIR FORCE - F-4E, F-111 (PAVE TACK)

PROVEN PERFORMANCE

1980'S

- O INCREASING IMPORTANCE OF FLIRS
- O SCENARIOS CHANGING
- O NEW WEAPON PLATFORMS

REQUIREMENTS BEYOND COMMON MODULE FLIRS

- O GREATER DETECTION/RECOGNITION RANGES
- O BETTER ADVERSE WEATHER CAPABILITY
- O REDUCED OPERATOR WORKLOAD
- O DECREASED SENSOR SIZE, WEIGHT, POWER

FOR: ASH, VSTOL A, F-16, ETC.

DEVELOPMENT APPROACH

- O MORE DETECTORS
- O AUTOMATIC OPERATION
- O IMAGE ENHANCEMENT
- O AUTO CUEING

DEVELOPMENTAL IMPACT

- O HIGH DENSITY FOCAL PLANE ARRAYS
- O 875 LINE TV FORMAT
- O AUTOPROCESSOR

DISPLAY ISSUES

- NEED TO INSURE SENSOR/DISPLAY COMPATIBILITY
  - HIGHER MTF
  - GREATER DYNAMIC RANGE
- NEED TO OPTIMIZE MAN-MACHINE INTERFACE
- NEED TO PROVIDE ADEQUATE PERFORMANCE WITHIN COCKPIT CONSTRAINTS
  - SMALL SIZE
  - HIGH AMBIENT BRIGHTNESS
  - LONG VIEWING DISTANCES

TRI-SERVICE DISPLAY WORKSHOP
17 January 1979

AF Next Generation FLIR

Presentation: FLIR Technology Demonstration Program

Andrew Grandjean
AFAL/RWI-2
Wright-Patterson AFB, OH 45433

Mission Analysis, Concept Formulation, Preliminary Design

The development of the design for the FLIR Technology Demonstration (FTD) program was based on Mission Analysis and Concept Formulation studies conducted during Phase I of that program that were to establish the operational requirements of the Air Force Next Generation FLIR (NGF). These requirements then played an important role in developing a concept for the Next Generation FLIR sensor. In the interaction of the Mission Analysis and the Concept Formulation, several key parameters were bounded. These parameter bounds were subjected to a tradeoff analysis and were further massaged by design and engineering considerations. Through this iterative process, the final performance requirements were derived, general sensor specifications formulated and, finally, a preliminary design generated that would demonstrate the postulated performance requirements.

The point of departure in the Phase I studies was the establishment of mission inputs. These were specified in terms of aircraft, weapons, tactics, defenses, world area, targets, missions, and atmospheric conditions.

As part of the concept formulation, a limited display study was performed. The display study dealt with how existing CRT technology, or advanced display technology, could satisfy the sensor/operator interface requirements in an aircraft such as the F-16. The F-16 imposes several size and weight limitations. The sensor performance requirements and the operator viewing distance impose stringent requirements on any display that would adequately match sensor performance with display/operator (psychophysical) considerations. General requirements were derived in terms of display MTF specifications, display size, display brightness, and ambient illumination.

The resulting system MTF, when the F-16 display is convolved into the sensor system, is not adequate. It was determined that the F-16 display has sufficient performance strictly in terms of display MTF but only at greatly reduced spot brightness levels, a condition that severely limits

the range of ambient illumination viewing conditions. An additional restriction, of course, is the display subtended angle at the 28 inch operator viewing distance.

As part of the Concept Formulation Task, two concepts were forwarded in connection with the display problem. One was a projected liquid crystal display (LCD), and the other was a CRT virtual image display (VID). The former is still a young technology; the later may be a viable near-term solution. The CRT video would have sufficient resolution to preserve inherent sensor performance, adequate brightness for day and night viewing, and offers a reasonable compromise between size of optics and the angular subtense of the presented image. The MTF curves under discussion are all illustrated in the presentation hard copy supplements.

The projected LDC display proposed as a long-term solution offers several potential advantages over current CRT technology: high contrast, grey shade capability under full range of ambient illumination levels, uniform high resolution, and significant reductions in power, weight, and volume requirements.

These initial concept recommendations are a first "attempt" in the process of defining next generation FLIR display requirements. It is recognized that a more sophisticated study must be performed that not only examines the current and future display technology trends, but will examine these in light of display modality and psychophysical considerations.

The FTD program is being developed in parallel, for incorporation with, auto screening and cueing hardware. This alleviates to some, as yet undetermined, degree the display/operator requirements. The high performance of the FTD sensor, in terms of MTF, and MRT, will be "used" by the autocuer, if not fully by the operator. While this is true, it is imperative that the ultimate operator display requirements be determined so that intelligent decisions can be made prior to hardware demonstration and design commitments in the advanced development programs to follow FTD. To this end, an MOA has been initiated between AFAL and AMRL that addresses the display issue. FTD sensor display requirements (in a lab scenario), in general, will be established. A matrix analysis of operator and interface requirements, display modality, S.O.A., FTD system requirements, and ambient conditions will be performed to provide the basis for two roadmaps and two statements of work to define display technology exploitation for the near- and far-term satisfaction of advanced FLIR sensor display requirements.

Advanced Tactical (ATAC) FLIR Program

Stuart F. Layman

Night Vision & Electro-Optics Laboratory
Fort Belvoir, Virginia 22060
Phone: (703) 664-5409

The past several years have brought about considerable interest in the development of detector/CCD processing that has led to system concepts employing high density focal planes containing thousands of elements. By increasing the element number and density, the system designer is enabled to have more flexibility in trading off resolution, field of view, and sensitivity. He can improve by a significant amount, the system stand-off range and the ability to penetrate poor weather and degraded visibility conditions. In general, the effect of these advances is to increase the information content coming off of the focal plane assembly. This information is then processed, formatted, and displayed to an observer. Considering that the displays for present generation systems were somewhat limiting, it becomes apparent that with an increased information throughput, the display and display/observer interface are even more critical in preserving the increased performance of the focal plane assembly. Specifically, first can the display MTF be made adequate and second can the imagery be presented to the observer in such a way that the eye makes maximum use of the information displayed?

Two programs are presently under contract for development of high performance second generation FLIR systems. One is the DA/DARPA funded Advanced Tactical (ATAC) FLIR and the other is the DA funded High Sensitivity Tank FLIR (HISTAF). The ATAC FLIR system is a technology demonstrator for airborne applications incorporating a CCD processed Si:In focal plane assembly operating in the 3-5u region. The system is being designed however in such a way that it could accept other focal plane materials and with slight optics changes could utilize an 8-12u focal plane. The Navy is developing an alternative 3-5u focal plane with InSb detectors (HYTAC program) which will be mounted in a dewar which will be a direct replacement for the Si:In dewar in the ATAC FLIR.

As part of this program, in order to help facilitate the observer's search task and enable the reduction of display limitations, automatic image processing techniques will be employed. These include automatic target cueing, automatic gain and brightness controls, and image enhancement using local contrast stretch techniques. The autocueing feature will enable the observer to automatically search a scene for high threat targets, detect and classify them, and then display them according to priority back to the observer in a zoom mode. The observer can then interrogate the target and make a decision for handing this target off to a missile seeker.

The HISTAF system is being developed for future combat vehicle applications and incorporates a high density focal plane using 8-12u PV HgCdTe detectors with CCD processing on the focal plane. The emphasis in this program is on high sensitivity for poor weather operation and degraded atmosphere penetration. The focal plane technology being developed under this program will be compatible with the common modules presently being used in the Tank Thermal Sight (TTS). The displays for both of the systems discussed here are 875 line TV format CRTs. In addition, the ATAC FLIR program is providing an 875 line virtual image display for integration in aircraft.

SESSION VI

SENSOR/DISPLAY STATE OF THE ART

DISPLAY OVERVIEW

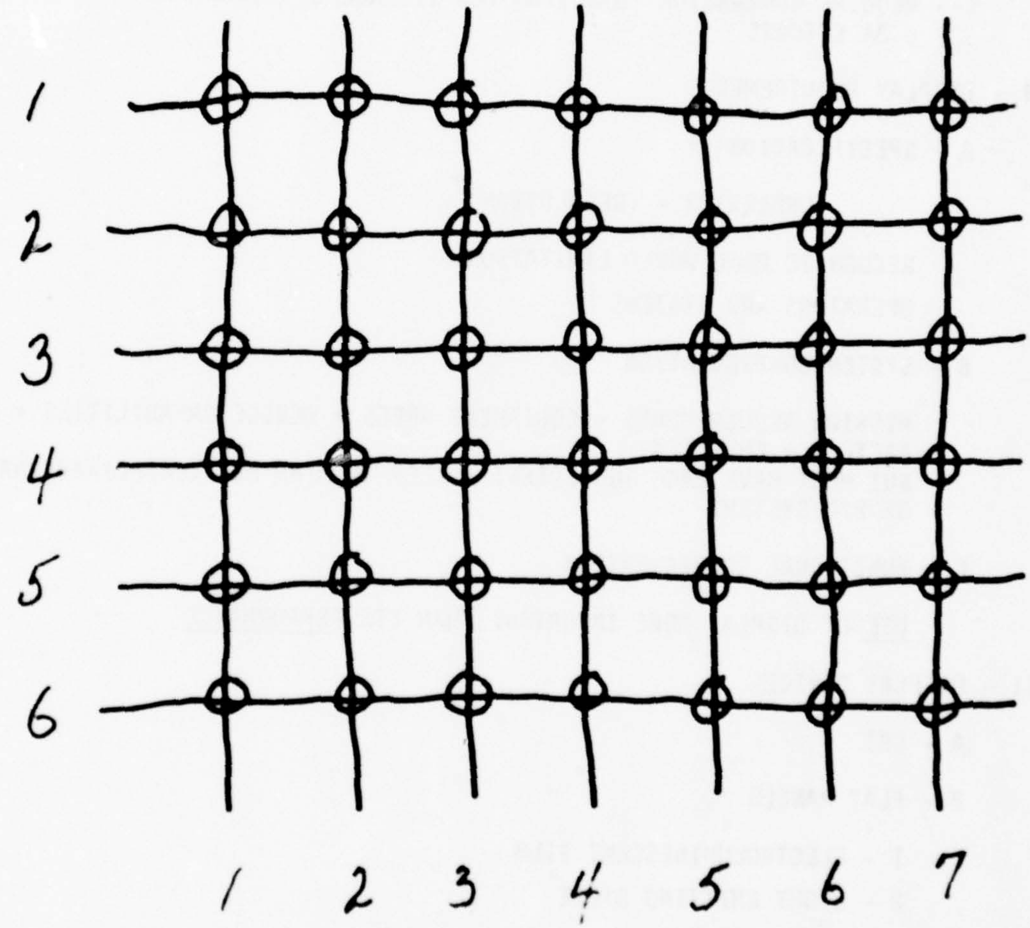
DIRECT VIEW FLAT PANEL DISPLAYS

Dr. E. Schlam

USAERADCOM

MATRIX ADDRESSING

FLAT PANEL DISPLAY



- <u>DISPLAY OVERVIEW</u>

I - TECHNOLOGY MANAGEMENT

II - DISPLAY REQUIREMENTS

III - DISPLAY DEVICES

I - TECHNOLOGY MANAGEMENT

A - SYSTEM SPEC MUST ADDRESS MAN/MACHINE INTERFACE--MUST RECOGNIZE IMPORTANCE OF DISPLAY

B - TELL CONTRACTOR WHAT IS EXPECTED OF HIM WITH REGARD TO MAN/MACHINE INTERFACE

C - REQUIRE CONTRACTOR TO DESIGN FOR TECHNOLOGY INSERTION--SUPPORT 6.3A EFFORTS

II - DISPLAY REQUIREMENTS

A - SPECIFICATION

$$\text{COMPLEXITY} = (\text{RESOLUTION})^2$$

RECOGNIZE REAL WORLD LIMITATIONS

OPERATORS AND SYSTEMS

B - SYSTEM CONFIGURATION

MISSION REQUIREMENTS + EQUIPMENT SPECS + DEVICE CAPABILITIES + HUMAN FACTORS = CONFLICT!
BUT MUST HAVE EACH INGREDIENT → KEEP IN MIND MULTISCIPLINARY NATURE OF E/O SYSTEMS

C - FUNCTIONAL CONFIGURATION

<u>USE</u> OF DISPLAY MORE IMPORTANT THAN ITS <u>PERFORMANCE</u>

III - DISPLAY DEVICES

A - CRT

B - FLAT PANELS

1 - ELECTROLUMINESCENT FILM

2 - LIGHT EMITTING DIODE

3 - LIQUID CRYSTAL

C - FUNDAMENTAL DIFFERENCE IS ADDRESSING DISPLAY ELEMENTS

1 - CRT → BEAM ADDRESSING VIA SERIAL ANALOG SIGNAL

2 - FLAT PANELS → DIGITAL ADDRESSING VIA PARALLEL MULTI-LEADS

(1) (2)

DISPLAY DEVICE → DISPLAY MEDIUM + ADDRESSING + PERIPHERALS

(1) ELECTRICAL → OPTICAL CONVERSION EFFICIENCY
    RESPONSE TIME
    GEOMETRICAL CONSTRAINTS
    ENVIRONMENTAL CONSTRAINTS
    OPTICAL PROPERTIES

(2) BRIGHTNESS (LUMINANCE)/CONTRAST
    FRAME RATE
    RESOLUTION

CRTs

Mr. H. Waruszewski/ASD/ENAIC

[Editor's Note: Unfortunately the illustrations shown during this presentation cannot be reproduced for the proceedings.]

SESSION VI

DIRECT VIEW DISPLAYS

Dr. E. Schlam

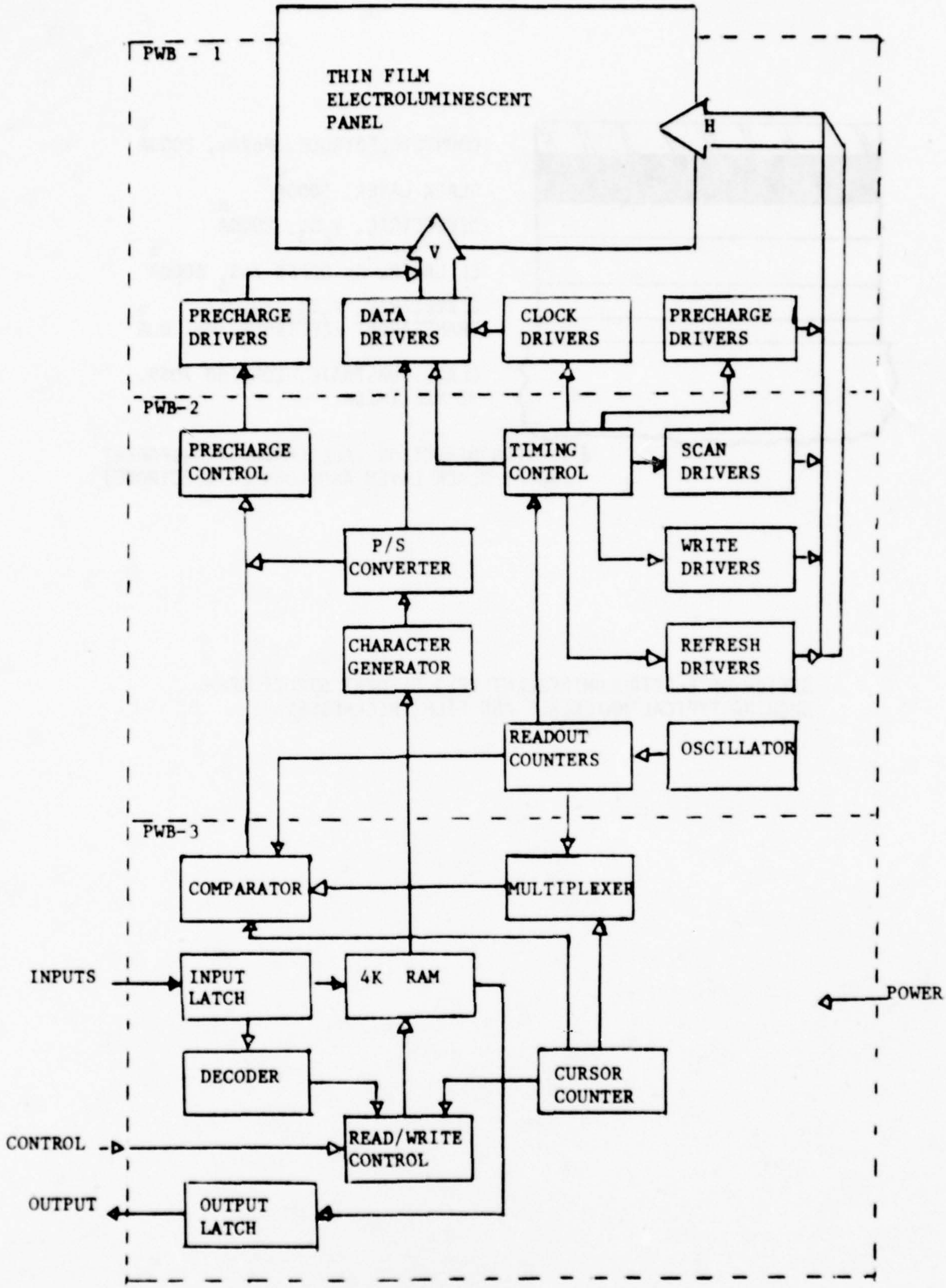
USAERADCOM

VIDEO DISPLAY TECHNOLOGIES

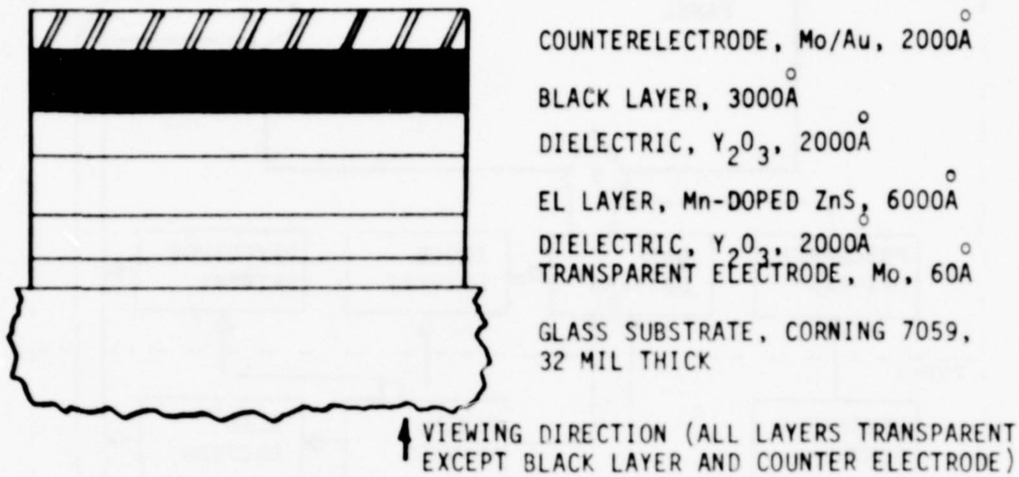
	FEATURES	LIMITATIONS
CATHODE RAY TUBE	MATURE TECHNOLOGY FULL COLOR VIDEO CAPABILITY CONVENTIONAL RASTER SCANNING	LOW CONTRAST HIGH POWER CONSUMPTION EXCESSIVE SIZE & WEIGHT HIGH VOLTAGE (>10,000V)
FLAT PANELS		
THIN FILM ELECTROLUMINESCENCE	HIGH CONTRAST LOW POWER REQUIREMENTS EASILY MULTIPLEXED	DEVELOPMENT STILL REQUIRED MEDIUM VOLTAGE (>100V)
LIGHT EMITTING DIODE	LOW VOLTAGE, IC COMPATIBLE EASILY MULTIPLEXED	LARGE ARRAYS ARE COSTLY HIGH POWER CONSUMPTION DEVELOPMENT STILL REQUIRED
LIQUID CRYSTAL	VERY LOW POWER SUNLIGHT LEGIBILITY LOW VOLTAGE, IC COMPATIBLE	DIFFICULT TO MULTIPLEX SLOW RESPONSE TIME TEMPERATURE LIMITATIONS DEVELOPMENT STILL REQUIRED

ELECTROLUMINESCENT DISPLAY
CHARACTERISTICS

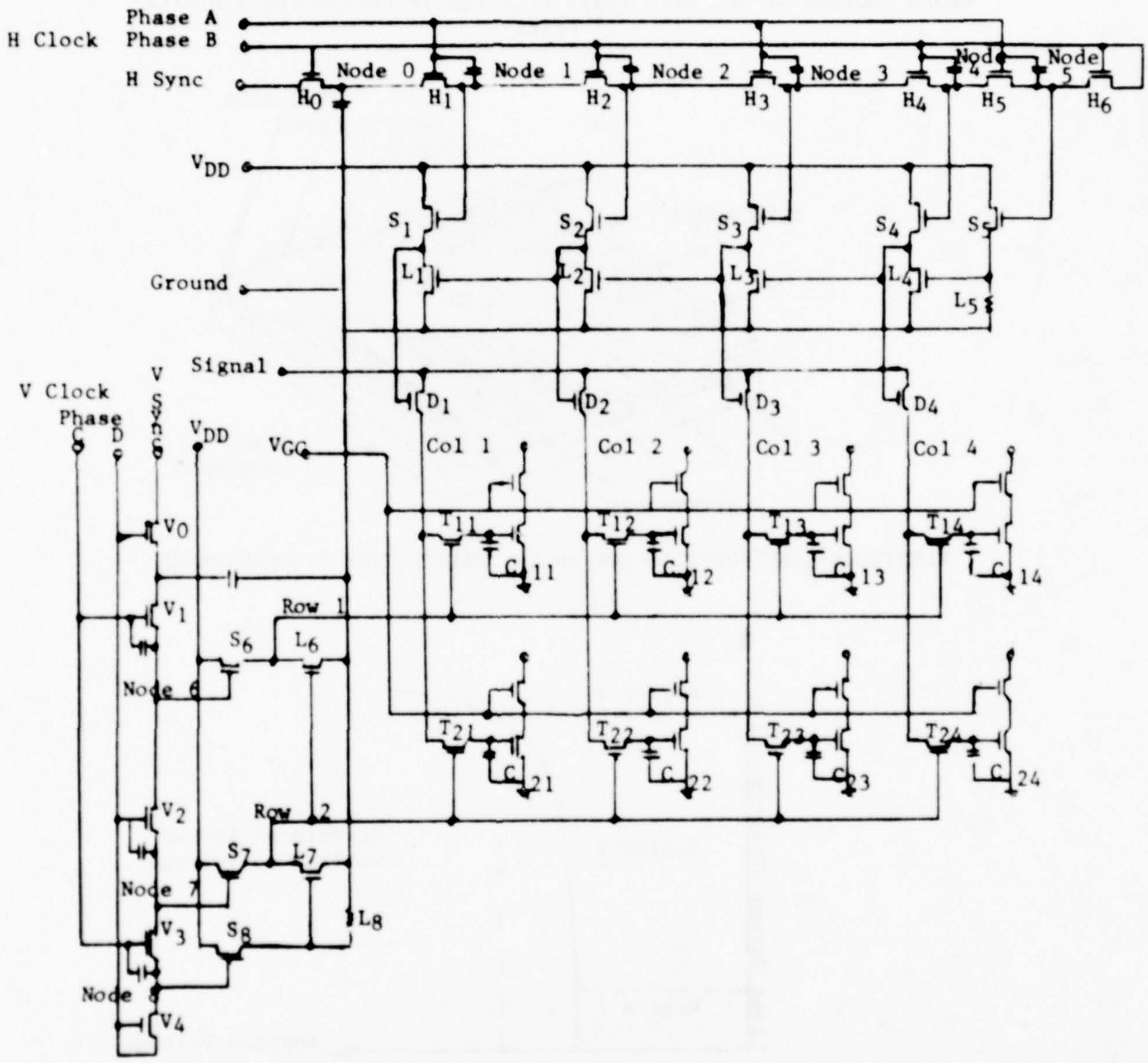
PARAMETER	CURRENT	NEAR-TERM	FUTURE
RESOLUTION	70 LPI	100 LPI	500 LPI
LUMINANCE	30 FL	60 FL	200 FL
CONTRAST	LEGIBLE IN BRIGHT ROOM LIGHTING	SUNLIGHT LEGIBLE	° ° °
POWER EFFICIENCY	4 LUMENS/WATT 1 LUMEN/WATT WITH DRIVER	1.5 LUMEN/WATT WITH DRIVERS	4 LUMENS/WATT WITH DRIVERS
OPERATING VOLTAGE	200 VRMS	100 VRMS	75 VRMS
POWER CONSUMPTION	3.2 WATTS FOR 8" OR 10"	2 WATTS	1 WATT
MULTIPLEXING CAPABILITY	240 LINES	500 LINES	WITH TFTs > 1000 LINES
OPERATING TEMPERATURE	0°C TO 70°C LIMITED ONLY BY PACKAGE SEAL	-55°C TO 125°C	-55°C TO 125°C
SIZE	6" DIAGONAL	10" DIAGONAL	LIMITED ONLY BY SIZE OF THIN FILM DEPOSITION EQUPMENT
COLOR	YELLOW	YELLOW & GREEN AVAILABLE	FULL COLOR



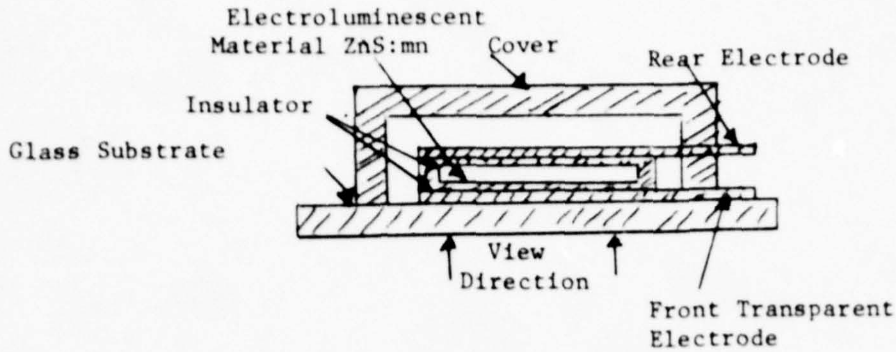
PWB - 1
THIN FILM
ELECTROLUMINESCENT
PANEL
H
V
PRECHARGE
DRIVERS
DATA
DRIVERS
CLOCK
DRIVERS
PRECHARGE
DRIVERS
PWB-2
PRECHARGE
CONTROL
TIMING
CONTROL
SCAN
DRIVERS
P/S
CONVERTER
WRITE
DRIVERS
CHARACTER
GENERATOR
REFRESH
DRIVERS
READOUT
COUNTERS
OSCILLATOR
PWB-3
COMPARATOR
MULTIPLEXER
INPUTS
INPUT
LATCH
4K RAM
POWER
DECODER
CURSOR
COUNTER
CONTROL
READ/WRITE
CONTROL
OUTPUT
OUTPUT
LATCH



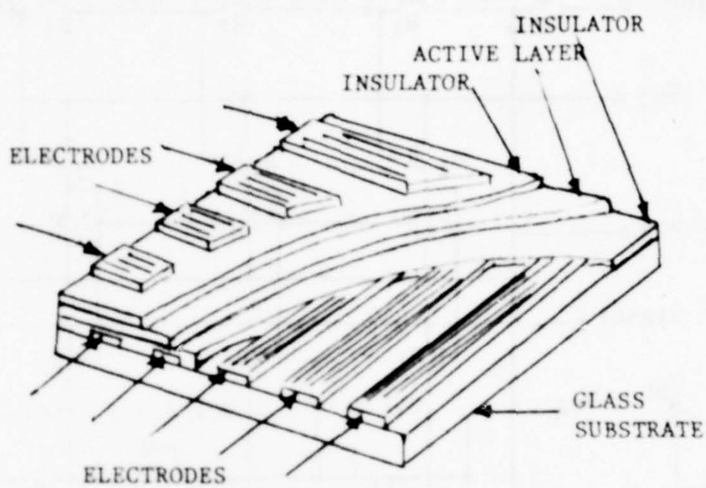
SKETCH OF ELECTROLUMINESCENT (EL) ELEMENT STRUCTURE--
SHOWING TYPICAL MATERIALS AND FILM THICKNESSES



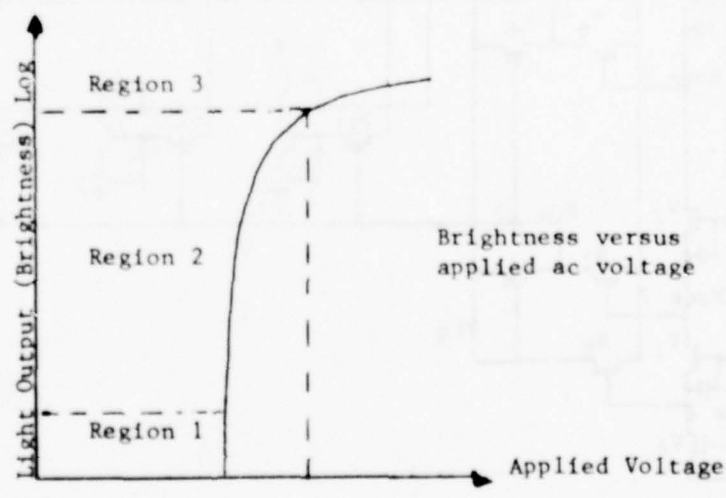
SIMPLIFIED DISPLAY ELECTRONICS CIRCUIT DIAGRAM FOR TFT SCANNING AND ADDRESSING



CROSS SECTION OF THE TFEL (THIN FILM ELECTROLUMINESCENT) DISPLAY PANEL



ELECTRODE CONFIGURATION FOR AN X-Y MATRIX TFEL DISPLAY PANEL



CUSTOM INTEGRATED
CIRCUIT DRIVERS

FEATURES

- O VIDEO RATES, FULLY INTERLACED
- O 20 VOLT LC DRIVE
- O PROCESS COMPATIBLE WITH THE ARRAY
- O CAPABLE OF DRIVING 350 ELEMENTS PER LINE
- O PERFORMANCE DEMONSTRATED

KEY ADVANTAGES OF

LIQUID CRYSTAL DISPLAY

- O HIGH CONTRAST IN SMALL AND LARGE AREAS
- O GRAY SHADE CAPABILITY UNDER ALL LEVELS OF ILLUMINATION
- O UNIFORM HIGH RESOLUTION OVER ENTIRE DISPLAY AREA
- O INTERFACE SIMILAR TOCRT TV DISPLAY
- O LOW POWER, WEIGHT, VOLUME

DISPLAY DYNAMICS ::::::::::::::::::::::HIGH DENSITY
REFRESH RATE 500 HZ
UPDATE RATE 50 HZ

- SMALL DEPTH ::: 3.5"
- LOW VOLTAGE ::: 10 VOLTS
- HIGH RELIABILITY:::11,500 HRS.
- ALL DIGITAL:::CMOS
- DISPLAY:::REPLACEABLE LED MODULES
- CONTRAST RATIO:::5 TO 1
- RESOLUTION:::64 LED'S TO THE INCH
- COLOR:::GREEN
- ALPHANUMERIC/VECTOGRAPHIC DISPLAY
- AUTOMATIC LUMINANCE CONTROL
- SELF TEST MODE
- REMOTABLE POWER SUPPLY

MULTI-MODE MATRIX DISPLAY

SPECIFICATION TYPICAL 5x6 IN. DISPLAY SURFACE

LED LUMINANCE	120 foot lamberts (through filter)
EMISSION WAVE LENGTH	5650 ± 50Å (GREEN)
RESOLUTION	64 x 64 LED Matrix per square inch
CONTRAST	4:1 minimum in 10,000 fc ambient
LUMINANCE UNIFORMITY	± 30% LED to LED
VIEWING ANGLE	± 45° from normal
CHARACTER SIZE	4 SIZES AVAILABLE a) 5 x 7 Dot Matrix - 0.078" x 0.11" b) 10 x 14 Dot Matrix - 0.157" x 0.22" c) 15 x 21 Dot Matrix - 0.235" x 0.33" d) 20 x 28 Dot Matrix - 0.214" x 0.44"
SYMBOL SET	Ten 5 x 7 Dot numerics Thirty-six 10 x 14 Dot Alphanumerics Thirty-six 15 x 21 Dot Alphanumerics Forty-six 20 x 28 Dot Alphanumerics and special symbols
GREY SCALE	3 levels
REFRESH RATE	500 Hz-internal
UPDATE RATE	50 Hz
COMPUTER INTERFACE	PDP 11. unibus architecture, modified ASC 11 format
RELIABILITY	11,500 Hrs. MTBF
MAINTAINABILITY	Full modular construction
CONTROLS	5 Mode selector: Off, Test, Vor, Tacan, ILS and INS
POWER	300 Watts max. 115 Volt, 3 phase, 400 Hz

TYPICAL PILOT'S DISPLAYS

APPLICATIONS

The Multi-Mode Matrix display's small size, lightweight and high resistance to shock and vibration make it suitable for many uses both civil and military.

- Vertical and horizontal flight situation displays for fighter and transport aircraft.
- Dynamic air-to-ground tactical displays for military aircraft.
- Navigation displays e.g.; INS, VOR, Tacan range and bearing, way points, Flight Director functions, ILS and MLS.
- Check lists, fault indication, system status and corrective action displays.
- Multi-purpose displays e.g.; engine data, fuel status, weapon status and warning indication.
- Communication displays.

HELMET-MOUNTED DISPLAY
DEVELOPMENT OVERVIEW

James H. Brindle

Army Night Vision & Electro-Optics Laboratory

INTRODUCTION This represents an overview of the Army/Navy/Air Force development of helmet-mounted displays (HMD). Many times the helmet-mounted display is combined with a helmet-mounted sight (HMS) to form a visually-coupled system (VCS). In this closed-loop interface between the operator and the avionics or weapon system involved, the HMS represents the control path and the HMD represents the feedback path. Although many applications involve the use of both these systems, and most helmets described are integrated systems incorporating both functions, the primary focus here is on the helmet-mounted display.

CONCEPT DESCRIPTION The helmet-mounted display is a collimated, virtual image type display which is mounted to or built integrally with the pilot's flight helmet. An HMD system conceptual implementation is shown in Fig. 1. The image is generated on a miniature image source (miniature cathode-ray tube or solid state array) with a display area of typically 1 inch diameter.

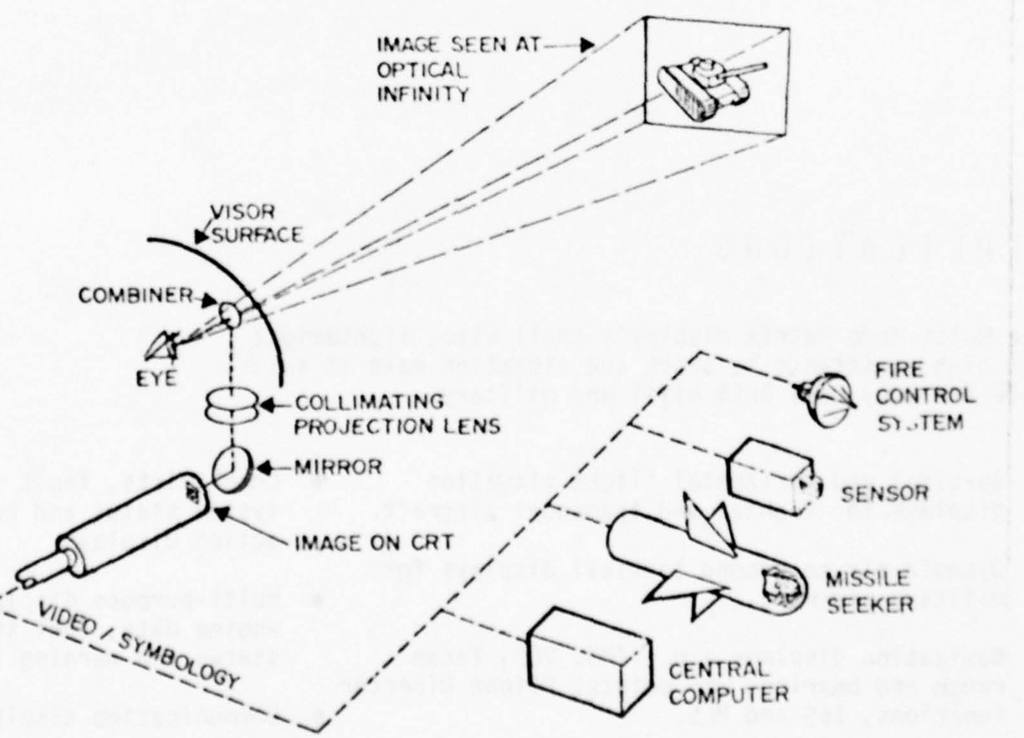


Figure 1 Helmet-Mounted Display Concept

The image is relayed from the miniature image source, mounted somewhere on the helmet, thru an optical system also on the helmet to a point where it is projected onto a final beamsplitter, or the visor, and into the pilot's eye. The pilot sees a virtual image of the displayed information, collimated at infinity, superimposed over his view of the real world. Because the display system is coupled to the head, the pilot has the capability for the system's wide field-of-view (FOV) for presentation no matter what his head line-of-sight might be, and therefore is not constrained to a head-down or boresight position to obtain the required display information.

A conceptual schematic such as Fig. 1 is useful for noting the areas which are key in the development of a system of this type, and which have the most impact on system performance, applicability, and user acceptance. Certainly the image quality or performance criteria for both the miniature image source and the helmet optical system are important in any system application. The field-of-view which the virtual image subtends at the eye is also an important system design parameter. The exit pupil, which is the amount of translation either vertically or horizontally allowable for the eye relative to the system on the helmet while maintaining the full field-of-view, is an important factor for system use in an extreme buffeting or high "g" environment. These environments, together with increasing mission length, place stringent requirements on the weight of the helmet system. Equally important is the placement of the additional components on the helmet in a manner which minimizes a change in the resultant center of gravity of the overall helmet system. Minimum size, as well as weight, is important to allow the pilot complete freedom of head movement within the cockpit. The system trade-offs at the combiner/visor in terms of display thruput efficiency and visibility, and background see-through characteristics should be made to optimize the system for the appropriate daytime, dusk, or night mission to be flown. Because the user is linked via an electronics cable from his helmet to an electronics unit on the aircraft, an appropriate means of quick dissconnect must be provided for ejection or rapid ground egress.

The helmet-mounted display is being used to present a variety of different types of information in response to the different mission segment requirements. A primary use is the presentation of high resolution video imagery from the various forward looking infrared (FLIR), daytime, and low light level TV sensors onboard the aircraft. This type of information is used for vehicle pilotage, target acquisition, weapon delivery, navigation, and terrain avoidance. The helmet-mounted display is also used for the presentation of a variety of different types of symbology. These range in complexity from simple gunsight reticles and discrete cues, to flight control and navigation symbology typical of head-up display presentation, complex space-stabilized weapon delivery symbology (utilizing the helmet-mounted sight), and vector graphics. An example of an off-boresight helmet-mounted display image with symbology overlay for a night mission is shown in Fig 2. In short, the type of information being presented by the onboard helmet-mounted display system covers the full gamut of information presented by any of the other modes of cockpit displays.

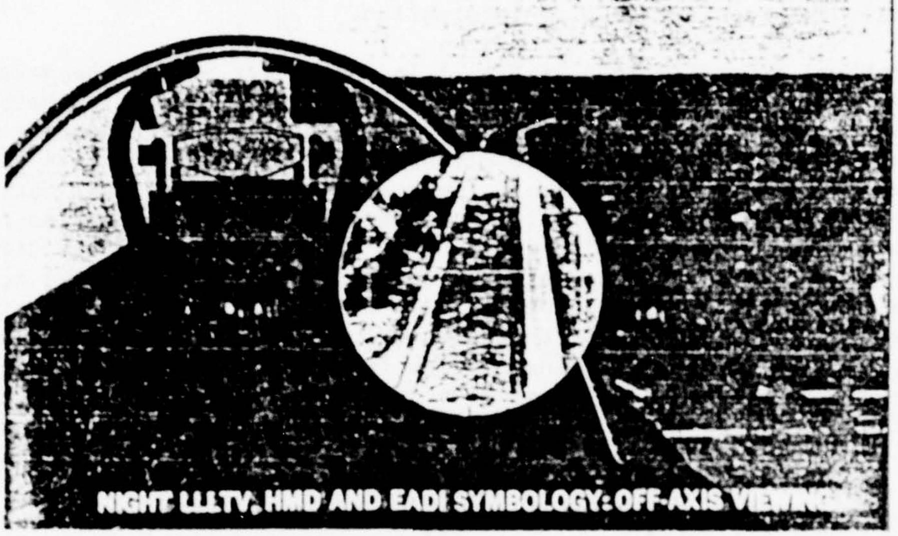


Figure 2 Off-boresight HMD Image with Symbology Overlay During Night Mission

STATE-OF-THE-ART OVERVIEW Generally, helmet-mounted displays can be grouped as completely integrated helmet systems with the displayed image projected off the visor and into the pilot's eye, or as separately attachable systems with combiners which can be physically removed from the helmet and stowed in the cockpit. Examples of these types of helmet-mounted display systems along with key performance characteristics of each are given here to provide a state-of-the-art baseline for these types of display systems. The Model 7A parabolic visor display is shown in Fig. 3. In this system the miniature cathode-ray tube is mounted on the rear of the flight helmet and the image is relayed over the top of the helmet via a coherent fiber optics bundle to the final collimation optics. It is then projected onto the visor at a point up out of the pilot's normal field of regard, back onto a central mirror which lowers over the forehead when the visor is lowered, back onto the visor at a point within the pilot's forward field of regard, and into his eye. This symmetrical "double bounce" approach using part of a paraboloid of revolution as the visor was chosen to minimize system degredations such as coma and astigmatism. The Model 7A is a 20° FOV system with a 10 mm exit pupil, and represents a total helmet system weight of slightly over 5 lbs. The Model 8 parabolic visor helmet-mounted display shown in Fig. 4, also employs the "double bounce" approach with a slightly larger paraboloid of revolution. The miniature cathode-ray

Figure 3 Model 7A Parabolic Visor Helmet-Mounted Display

Figure 4 Model 8 Parabolic Visor Helmet-Mounted Display

tube is integrated into the helmet over the earcup. An optical relay system brings the image around where it then goes through the double bounce to the eye. The Model 8 is also a 20° FOV system with a 12 mm exit pupil and represents a total system weight of slightly over 4 lbs. In both the Model 7A and Model 8, as mentioned earlier, the characteristics of the reflective coatings on the visor as well as the transmission coefficient of the visor material are tailored according to the day/dusk/night mission to be flown. These parabolic visor displays represent helmet-mounted display development at the 6.4 level. Shown in Fig. 5 is an example of a holographic visor helmet-mounted display. The miniature cathode-ray tube utilizes a phosphor with a narrow spectral bandwidth output, and this is matched by the spectral response characteristics of the diffraction optical element integrated into the visor. The characteristics of this system are a 30° FOV, a 15 mm exit pupil, and a helmet system weight (excluding HMS function) of slightly over 3.5 lbs. Holographic visor helmet-

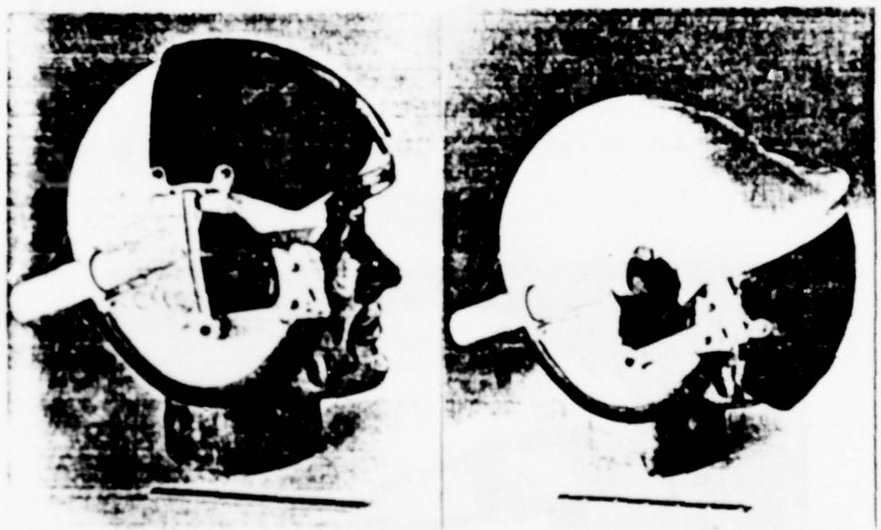


Figure 5 Holographic Visor Helmet-Mounted Display

mounted display efforts are currently at the 6.2/6.3 level of development. These examples of visor projected helmet-mounted displays, including both parabolic visor displays and the holographic visor display, require some degree of predistortion of the image on the miniature image source so that, when viewed through the system as a whole, the image appears rectilinear to the pilot.

The helmet-mounted display unit pictured in Fig. 6 is representative of the separately attachable class of helmet-mounted display systems. This particular HMD system is part of the Integrated Helmet and Display Sight System (IHADSS) shown in Fig. 7. As such, it represents the HMD system which is at the most advanced stage in the development cycle since the IHADSS is entering production for operational use on the Army's Advanced Attack

Figure 6 IHADSS Helmet-Mounted Display Unit

Helicopter (AAH). The system in Figure 6 has a 30° vertical x 40° horizontal FOV, a 10 mm exit pupil, and represents a total helmet system weight of slightly under 3.5 lbs. In this system, the visor of the flight helmet is lowered to cover the final combiner of the HMD optical system, and the transmission coefficient of the polycarbonate visor is selected to optimize system use for a given day, dusk, or night mission. No predistortion of the image on the miniature cathode-ray tube is required in the IHADSS HMD system. A separately attachable system like the IHADSS HMD, with a moveable combiner and the ability to rotate around the axis of the miniature CRT in the "C" clamp on the helmet, facilitates any adjustment required to accommodate pilots with a wide range head characteristics and interpupilary distances. Eyeglass compatibility is a design objective for systems of this type.

Figure 7 Integrated Helmet and Display Sight System for Army Advanced Attack Helicopter

All of the representative examples of state-of-the-art helmet-mounted display systems described above are monocular helmet optical systems. As a part of various laboratory experimental investigations, biocular and binocular helmet-mounted display configurations have been implemented. This has been accomplished, in some cases, simply by using two separately attachable HMDs, with one being attached on each side of the flight helmet. In other cases, such as the system shown in Fig. 8, a small cathode-ray tube generates the required image which is then relayed around inside the helmet via two separate fiber optics bundles and thru two projection lens assemblies located near each temple. The image is then projected onto discrete segments or areas on the inside of the specially configured visor assembly. Both conventional and diffraction optical approaches have been considered for this aspect of the overall helmet optical system. In addition to all of the monocular helmet-mounted display development criteria, several factors unique to binocular HMD systems should strongly influence their development and application. Minimizing optical system distortion and/or achieving an equivalent distortion pattern for the FOV presented to each eye is

Figure 8. Experimental Binocular Helmet-Mounted Display

extremely important in order to reduce operator fatigue caused by trying to mentally fuze two dissimilar images. The weight associated with the dual optical relay and projection systems should be minimized, and this factor should be considered in relation to application and mission length. The ability of a binocular helmet-mounted display to present stereoscopic imagery and symbology is an important factor to consider in overall system configuration for a given application. Implementations such as these currently represent work at the 6.2 level of development.

Almost all state-of-the-art helmet-mounted displays currently utilize a miniature cathode-ray tube such as the one shown in Fig. 9, as the image source. This ruggedized, or productized version represents the combined results of a long series of development efforts to reduce the size and weight of the tube as well as improve its performance. Reduced length and diameter have been combined with improved packaging. The incorporation of shaped fiber optics faceplates has reduced deflection defocusing and resulted in significant image quality improvement by reducing halation within the CRT faceplate. In helmet-mounted display systems, the miniature cathode-ray tube, together with its drive electronics unit (DEU), should be compatible with current 525 and 875 line sensors. Display

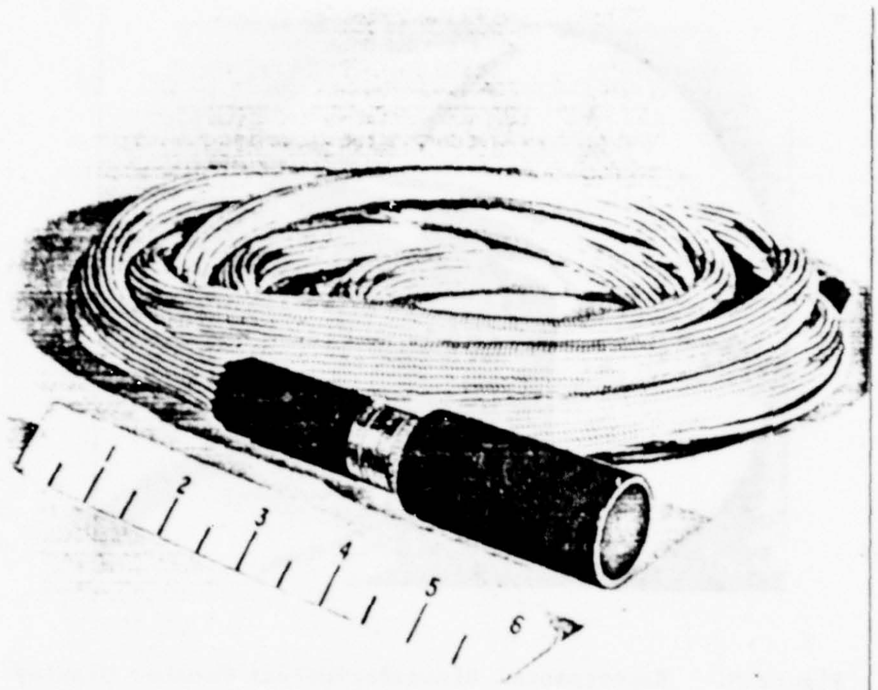


Figure 9 Productized Miniature Cathode-Ray Tube

refresh rates are at least 30 times per sec. and the accuracy and update rate for the HMD system should be compatible with the presentation of flight control and weapon delivery information in several of its modes of operation. These systems are capable of displaying in excess of ten 2 grey shades. The typical image quality for these types of systems is shown in Fig. 10. This figure shows general sine wave response (SWR) characteristics expressed as actual percent modulation measured photometrically at the output as a function of a sine wave electrical input to the system expressed in terms of cycles per raster width. The improvement on system performance as the peak luminance is reduced from 600 ft.L to 50 ft.L can be noted. Although not shown on this graph, a further improvement in performance can be obtained as the peak luminance is reduced to the 10 ft. L range characteristice of night operation. Current HMDs are single color systems, with various phosphors being utilized depending on other systems considerations.

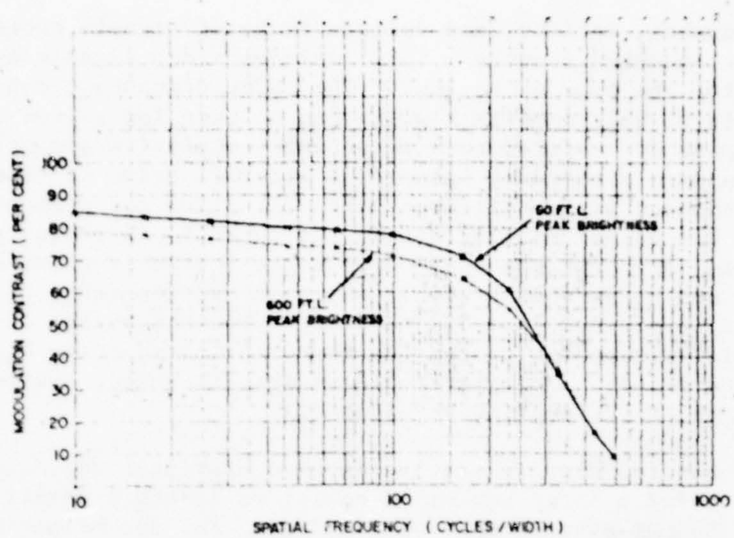


Figure 10 Typical Miniature CRT Response Characteristics

As noted earlier, an operator using an integrated helmet-mounted sight/display incorporating not only the miniature image source, but also the head position sensing system electronics and perhaps other specialized electronic functions is connected via an electronics cable to his various subsystems onboard his vehicle. An appropriate, explosion-proof means of quick disconnect must be provided to allow ejection as well as safe, rapid ground egress. Such a helmet-mounted electronics quick disconnect connector is shown in Fig. 11. The system has been engineered to handle

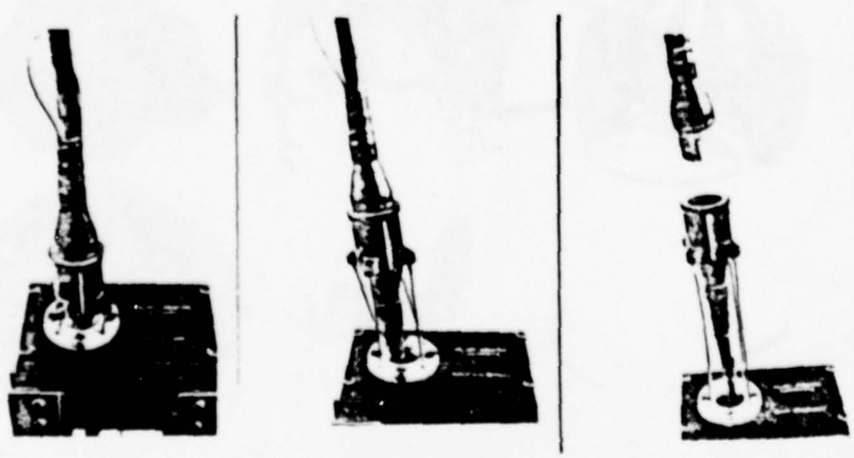


Figure 11 Helmet-Mounted Electronics Quick Disconnect Connector

the full number, variety, and voltage range of signals currently associated with helmet-mounted systems. This includes video signals and accelerating voltages for the tube up to 10KV. The quick disconnect connector features a short pin 28 volt interlock which can be used for system shutoff so that no "hot" pins are exposed to a potentially explosive atmosphere in the event of system disconnect onboard an aircraft prior to takeoff. The quick disconnect system pictured here will allow for some movement of the pilot and his helmet cabling within the cockpit, as shown, prior to system disconnect. Although the operator's helmet cable is attached to his harness assembly, and it is this assembly which incurs the force of system quick disconnect, a minimum force is required for cable system disconnect. The entire quick disconnect system has been fabricated using high impact plastics for minimum weight. This particular quick disconnect system is at the qualification state of engineering development.

As helmet-mounted display systems enter operational use across the services, the ability for a large number of operators to use a relatively smaller number of helmet systems must be provided. For the helmet-mounted display, along with the helmet-mounted sight, this means the ability to accommodate a large variety of operators having different head sizes, facial characteristics, interpupilary distances, etc., with the number of helmet-mounted systems available. In doing this it is necessary to insure that every operator's eye is at the design eye, or exit pupil location of the overall helmet optical system. Several techniques have emerged for successfully accomplishing this by means of properly forming or fitting the helmet liner subassembly. In all cases a modular approach toward configuring the complete helmet system has been taken. In the case of the IHADSS modular helmet system shown in Fig. 12, the web suspension subassembly is fit to the individual operator

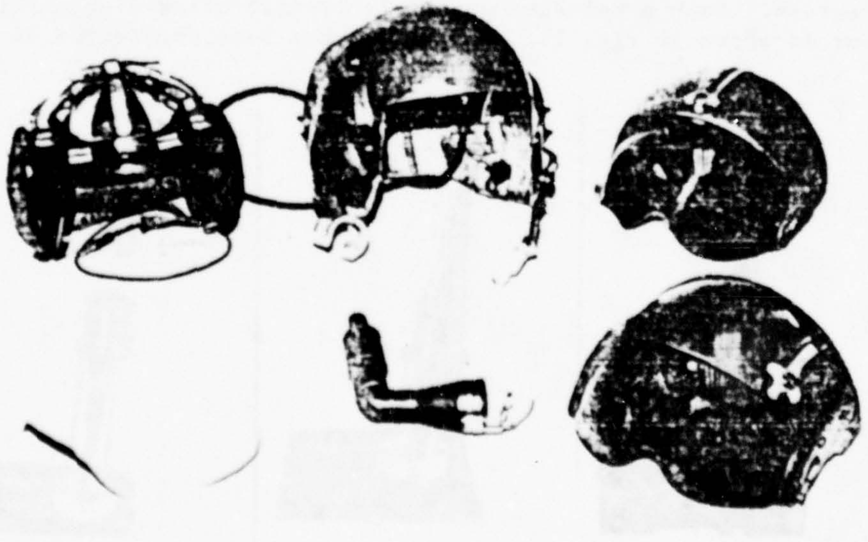


Figure 12 IHADSS Modular Helmet System

using an added reticle fixture to insure the user's eye is in proper position relative to the subassembly. As can be noted in the figure, the web suspension subassembly contains several rigid channels across the brow and along the side edges. When inserted into the helmet system shell, these insure proper eye position relative to the overall helmet optical system.

The other principal technique used for helmet-mounted sight or helmet-mounted display helmet system alignment is the poured foam type form-fit, or custom-fit liner. The operator's custom fit helmet liner is poured to conform to the inside of the specific helmet shell on its top surface, and to his head, of course, on the inside surface. As in the previous technique, the mold/fixture for accomplishing this contains a reticle to insure, while pouring the helmet liner, that the pilot's eye will be in the exit pupil location for the helmet optical system.

MAJOR DEVELOPMENT THRUSTS Along with other areas, helmet-mounted display/virtual image display development across the services is in the process of a major development thrust toward a solid state capability. This is conceptually illustrated in Fig. 13. In the case of the helmet-mounted display mode, or class of displays, there is a family of Tri-Service

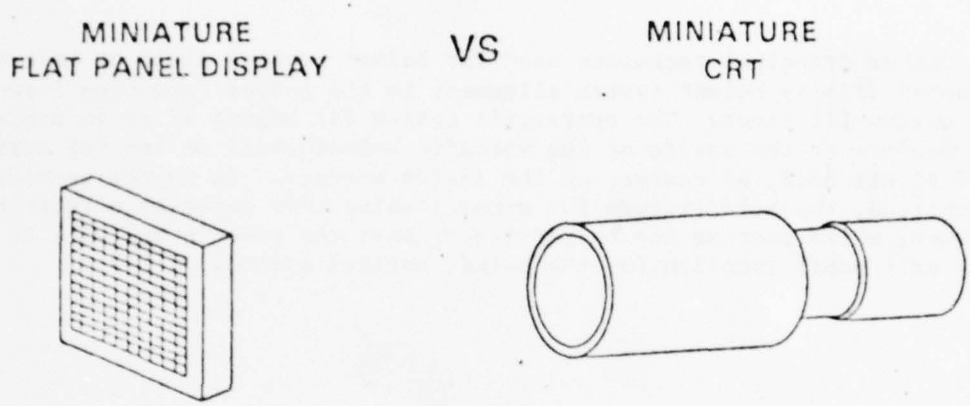


Figure 13. HMD Image Source Comparison

coordinated and sponsored development efforts aimed at achieving this solid state HMD capability in the most efficient and technically sound manner. After surveying the full range of solid state, or flat panel display techniques, several were identified for further analysis into their ability to meet the high resolution, high performace demands unique to the helmet-mounted display. As can be seen from Fig 14. this has resulted in the pursuit of the crossed electrode thin film electroluminescent (TFEL) and the liquid crystal-silicon (LC) approaches. In otherwords, via a coordinated Tri-Service set of activities, an intelligent process of elimination quickly resulted in the development efforts focusing on the two approaches with the highest payoff potential for the helmet-mounted display. Each of these approaches has its own unique advantages for an integrated helmet-mounted display system for specific mission applications, and its own set of development questions to be answered. As a class of imaging display sources, they offer additional system advantages to be discussed later. With a density of 500 lines per inch or greater having been demonstrated for both the TFEL and LC approaches via a 100 x 100 element array, development efforts have concentrated on miniature 525 line TV compatible image sources in

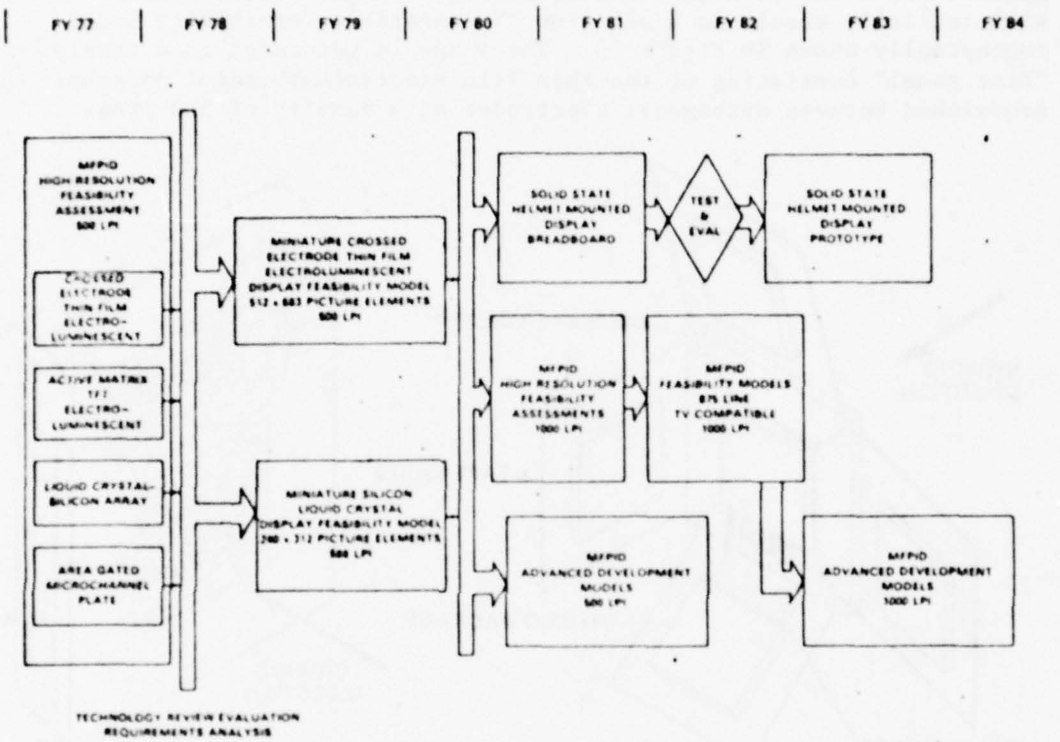


Figure 14. Miniature Flat Panel Imaging Display Development Chart

conjunction with advanced solid state helmet-mounted display development efforts. Advances in higher resolution miniature projection display image sources, advanced optics, and integrated helmet technologies will be combined in an iterative development process proceeding toward an 875 line TV compatible day/night solid state helmet-mounted display capability.

One of the parallel development efforts on miniature, high resolution imaging display sources utilizes the crossed electrode thin film electroluminescent approach. The development of an extremely high resolution TFEL display source capability specifically for the specialized class of helmet-mounted/virtual image display systems will initially result in a 525 line TV compatible feasibility model conceptually shown in Figure 15. The image is generated in a truely "flat panel" consisting of the thin film electroluminescent phosphor sandwiched between orthogonal electrodes at a density of 500 lines

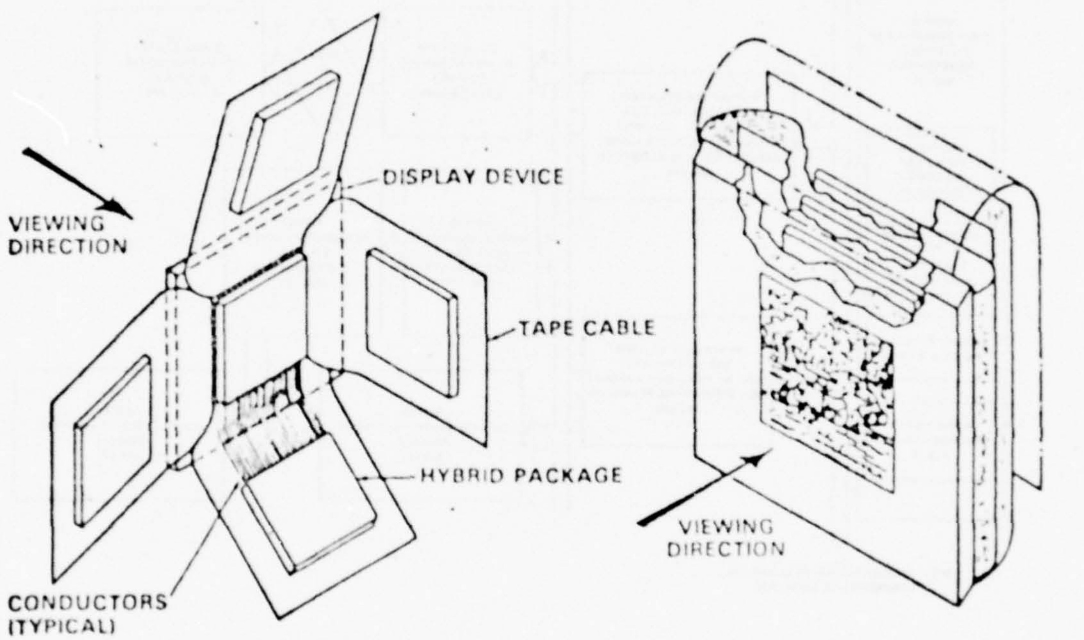


Figure 15. Miniature High Resolution TFEL Display with Attached Hybrid Drive Electronics

per inch. The image format of this display is 500 x 683 picture elements. This imaging substrate is connected with all of the hybrid drive electronics by means of flexible cabling. The hybrid drive electronics can therefore be folded around behind the display or follow the contour of the helmet shell. The other unique advantages of this approach are the truely flat panel nature and relatively simple construction of the imaging system. One major question area to be addressed during development efforts is the successful inter-connect at extremely high line densities. The incorporation of memory phosphor techniques to raise the peak luminance capability of this display approach is also an area for investigation. Typical performance characteristics to date for imaging displays of this

type include a peak luminance of 10-20 ft.L, the capability for a minimum of eight ?? grey shades, and a broadband orange spectral output. Incorporation of memory phosphor techniques could provide a 200-400 ft.L luminance capability. This approach represents a very low power display capability. Since this imaging display source is part of an overall, virtual image projection system, and is therefore never viewed directly, black layer techniques applicable for improving display contrast and viewability in direct sunlight with moderate display luminance are not applicable in this display mode.

Another of the parallel development efforts on miniature, high resolution imaging display sources utilizes the liquid crystal-silicon approach. This effort will initially result in a 525 line TV compatible feasibility model. The development of an extremely high resolution liquid crystal-silicon display source capability specifically for the specialized class of helmet-mounted/virtual image display systems will initially concentrate on the high resolution integrated display chip shown in Fig. 16. The imaging area of the silicon chip consists of an array of

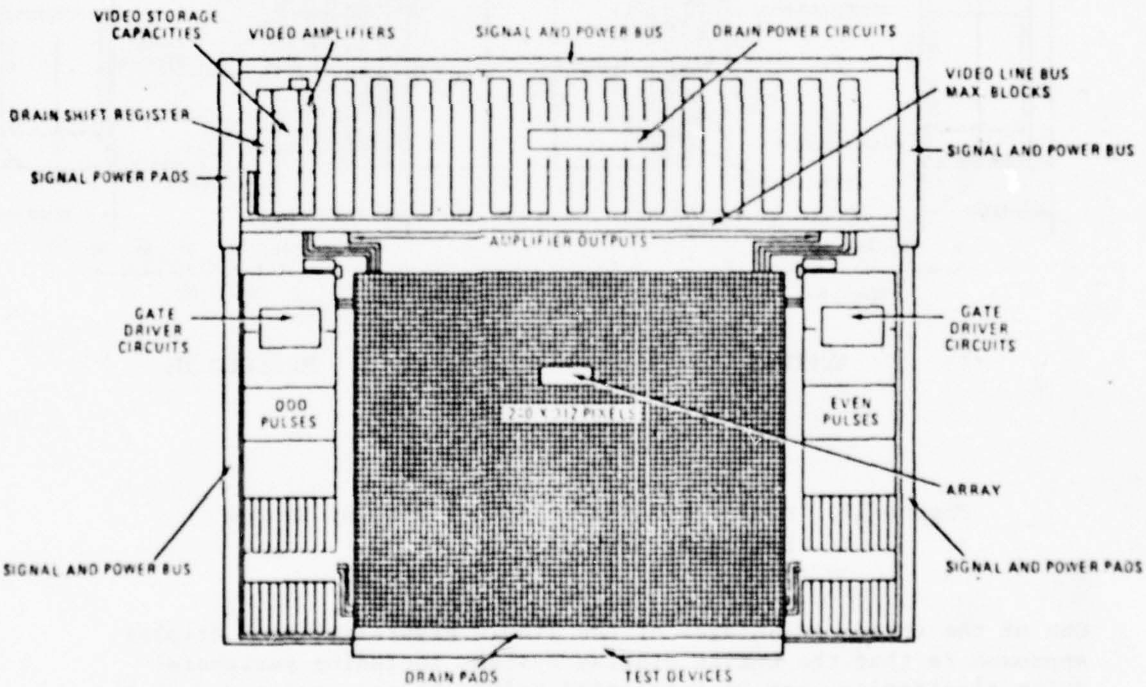


Figure 16 Miniature High Resolution Liquid Crystal-Silicon Display Chip with Integrated Drive Electronics

240 x 312 picture elements, with a MOS FET and capacitor located at each picture element site. The picture element density for this display is 588 per inch. The chip includes the integrated electronics for driving the display located around the periphery of the imaging area on the same silicon chip. This therefore represents a total of over 75,000 active elements on a single chip, which is at the leading edge in terms of the state-of-the-art of the silicon semiconductor industry. In this initial display, 525 line TV compatibility is achieved by displaying the second field on the same elements used to present the first field, while still maintaining a 60 Hz field rate. Since the liquid crystal display is a passive, or light modulating display approach using the dynamic scattering effect in the liquid crystal, a light source must be incorporated into the system design. Fig. 17 shows several of the various illumination/projection schemes under consideration for the helmet-mounted display.

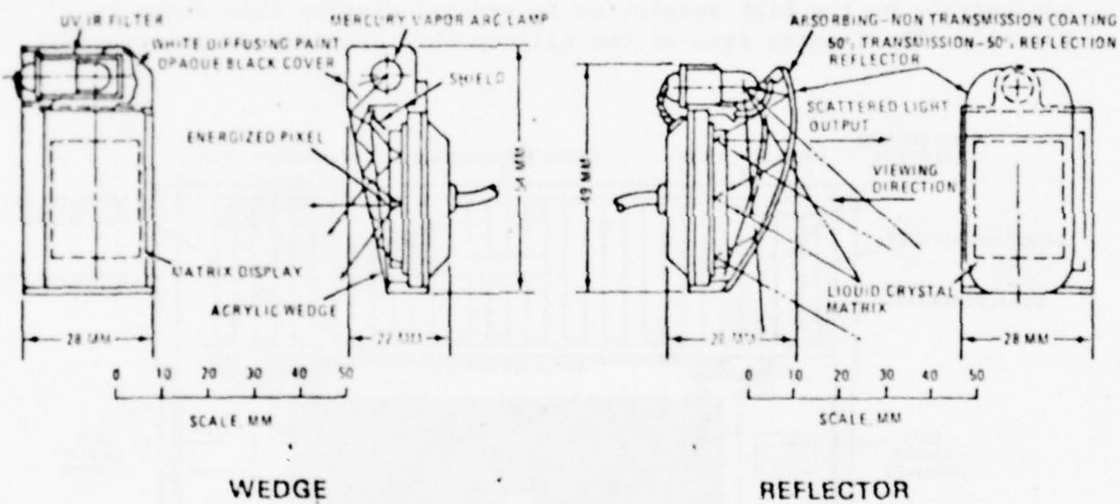


Figure 17. Miniature Liquid Crystal Display Source Packaging Schemes

One of the unique advantages of the liquid crystal-silicon display approach is that the entire display system, including peripheral drive electronics, can be fabricated using the same processes on the same chip, thus avoiding any high density interconnect situations. The large commercial technical base and ever-increasing level of complexity in the silicon semiconductor industry certainly benefit this development. The illumination source/projection scheme inherent in this approach offers high brightness potential. Since the illumi-

nation source is chosen with overall systems considerations in mind, the spectral output of the display (both peak wavelength and bandwidth) can be tailored to be compatible with a variety of conventional and diffraction optical systems. The size and optical interface with the resulting display source "packaging" scheme must, of course, be considered in an overall system design. One major question to be addressed during development efforts is that of yield for a chip of this complexity and area. The response time associated with a liquid crystal display is, in part, inversely proportional to the thickness of the liquid crystal layer. A part of the development effort should therefore be a sufficient control of the cell thickness and uniformity of spacing over the display area to achieve a response time which is commensurate with video display rates.

Both of the solid state imaging display source approaches being pursued are line-at-a-time addressed displays. The rows of the display are sequentially addressed, and the video information for an entire line is entered and displayed at once via the columns. Both display techniques are relatively low voltage approaches. Typical operating voltages are 200 volt for the TFEL and 30 volts for the LC as compared to 7KV for the anode voltage in miniature cathode-ray tubes. Both of these approaches represent a relatively low power display capability, with typical display system power consumption under 2-5 watts. Of course both types of imaging display sources offer a small size, light weight unit for system integration. Mockups of the two solid state image source approaches are shown in Fig 18. with the miniature CRT currently being

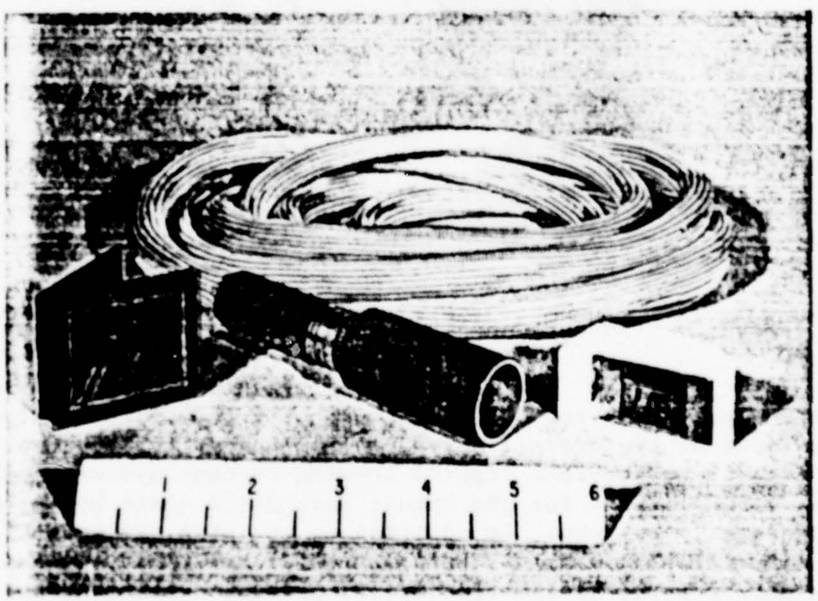


Figure 18 Miniature Solid State Display Mockups with Current Miniature CRT

used. In this type of development for advanced helmet-mounted displays, it should be kept in mind that the small imaging display source must be capable of presenting all of the information required in system use. The modular, or building block approach to achieving a high resolution display capability is not applicable to this class of display systems.

The overall system development of advanced, solid state helmet-mounted displays is conceptually represent in Fig. 19. Various design approaches are currently under consideration, along with both conventional and diffraction optical techniques. Investigations into the state-of-the-art

Figure 19 Advanced Solid State Helmet-Mounted Display

in repeatable, precision replication of aspheric plastic optical elements is another facet of the overall development process in this area. In comparing Fig. 19 to previous figures showing current system capabilities, one of the driving forces for the thrust into solid state helmet-mounted displays can easily be seen. In addition to the size and weight savings for the imaging display source alone, the solid state display source provides a much greater design flexibility for the overall helmet system. The "flat panel" nature of the image generation assembly opens up new design options for locating the unit in a more favorable position for projection onto a combiner/visor and eliminating the weight and bulk

associated with at least a portion of the typical HMD optical relay system. Significant overall helmet-mounted display system weight savings would open up the potential for an operational binocular capability in this class of display systems.

In addition to a major thrust toward a solid state capability in helmet-mounted displays, other development efforts are currently ongoing or in formulation to provide a short term improvement increment in system performance and inplementation, new system applications, and provide an advanced long term capability for multi-color and "smart" HMDs including integral processing. Improvements in the electron gun/electron optics associated with the miniatrure cathode-ray tube are intended to provide a short term improvement in performance of the tube. Application of intagliated phosphor techniques in the fiber optics faceplates of the miniature CRTs is aimed at reducing light spread throughout the phosphor layer, and eliminating any sine wave response degredation due to this spread. Qualification testing on the quick disconnect system would provide an improved aircraft integration capability for helmet-mounted systems. Extremely wide field-of-view design efforts are aimed at providing a laboratory based HMD capability for simulation and training where systen bulk, weight, and helmet center of gravity effects are not as important design parameters as FOV. Long term development efforts would provide advanced helmet-mounted displays with a multi-color and integral processing capability.

DEVELOPMENT RATIONALE The rationale for the major Tri-Service development thrusts associated with advanced helmet-mounted displays is to provide the wide field-of-view virtual image display capability required by a wide variety of systems implementations in such a way as to not limit or severely degrade overall system performance by that display capability. These trusts, in developing a low cost, light weight, high resolution display capability, are aimed at the full range of applications for this mode of display from visual sighting/ target acquisition to vehicle pilotage to fire control/weapon delivery. Key factors behind these development thrusts are highlighted in this section.

Wide Field-of-View As the amount of information available from advanced performance sensors increases, wide FOV displays are required to adequately present this information to the operator, even in an optimum viewing environment. Characteristics of the actual operating environment including the typical range of background brightnesses, target contrast, eye adaptation levels, target motion and relative motion between the normal display and the operator effect visual acuity to drive up FOV rquirements. Display usage for mission segments such as vehicle pilotage, with requirements for one-to-one magnification of the information presented and peripheral vision motion cues, puts

further pressure on achieving a wide FOV capability. The visual angular subtense of various display types is shown in Fig. 20. Developers of advanced generation sensors cite the need for a 17 inch display, a tough requirement in any vehicle, airborne or groundbased. What is

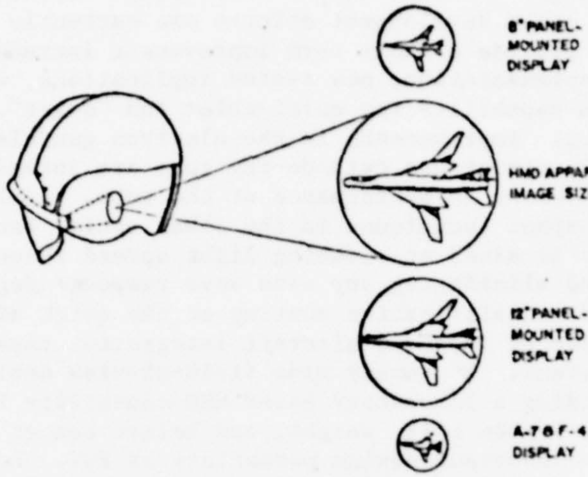


Figure 20 Helmet-Mounted Display Visual Angular Subtense Comparison

really being cited is the need for the performance of a 17 inch display, including its angular subtense to the operator. The advanced helmet-mounted display thrusts described earlier are aimed at providing the required display capability.

Out-of-the-Cockpit Display Capability The advanced helmet-mounted display development efforts provide a generic display capability for those instances when the operator requires a variety of video and symbolic information while maintaining an out-of-the-cockpit line of sight. This "see-through" display capability maintains the view of, and allows display interaction with the outside world. The off-boresight capability inherent in the helmet-mounted display allows the operator to make use of the system's wide FOV no matter what his line-of-sight. This is important as the task loading of the operator increases.

Ease of Vehicle Integration The helmet-mounted/virtual image class of displays are unique in that they require little or no front panel space in the cockpit other than that space required for control panel functions. Their display capability is therefore provided without competing for the ever decreasing front panel space in advanced military aircraft or groundbased vehicles. This is particularly important in the case of retrofitting existing vehicles.

Improved Performance The thrust toward a solid state capability for advanced helmet-mounted displays is, aimed at improving overall display performance. The development of high resolution displays must, of course, keep pace with increasing sensor performance. The solid state HMD display thrust, by going to a discreet element type display, is aimed at improving the dynamic range of the display system, especially at higher spatial frequencies. Display luminance ranges should be pursued in development which will allow the improved display performance over the full range of day/night operating conditions. Overall display uniformity improvements are possible by going to a solid state type system.

Improved Physical Characteristics As noted earlier, the solid state or flat panel image source associated with advanced helmet-mounted displays will result in a size and weight savings over current image sources such as the miniature CRT. Almost more important, however, is the increased helmet system design flexibility which can result in even greater weight savings and size/center of gravity improvements in the overall helmet-mounted display system. With increasing mission length, this is extremely important for maximum user acceptance of this class of display systems.

Accurate/Digital Type Display The development efforts toward a miniature high resolution solid state display will result in a matrix element array type display with the capability for accurate location within the field-of-view of the displayed information. This digital type display is therefore in keeping with the overall trend toward digital fire control and information processing systems of both current and future military vehicles.

Parallel Input Display The miniature solid state display development efforts referred to earlier will result in a line-at-a-time addressed display system capability. As noted in an earlier section, the video information for an entire line is entered into the display at once and presented to the operator. If the sensor collecting information for presentation on the display is collecting that information a line at a time, than a parallel input display capability would be desirable. Information would not have to be serialized to interface with a serial input type display system such as a cathode-ray tube. The CRT would, of course, then present the information element by element in a serial, or scanning manner. An echelon of electronics at both the sensor and display end of the overall system could be eliminated and system bandwidth constraints partially eased.

Power Reduction The development efforts toward an advanced solid state helmet-mounted display will make a significant reduction in the power requirements for this type of display system. The power requirements for a complete solid state display system would be typically 2-5 watts, and could be as little as several hundred milliwatts depending on the approach chosen, display area, and peak luminance required. This compares with system power requirements on the order of 50-100 watts for the miniature CRT and associated drive electronics.

Display System Cost Reduction One of the major driving factors behind the development thrusts toward an advanced solid state helmet-mounted display capability is the resulting cost reduction for a system of this type. The impact of this would be to make HMDs an even more cost competitive display mode alternative. Based on production analysis for the technological approaches being pursued, a complete display system cost of several thousand dollars is forecast for quantities in the hundreds. This is a factor of four to ten reduction over current miniature CRT/drive electronics cost projections for similar quantities.

The characteristics of the helmet-mounted display system have varied over the years of its evolution based on the technologies being applied to its implementation and the various application requirements for this mode of display. Current HMD systems could be described from the quite similar requirements for this type system posed by its application in the Army's Advanced Attack Helicopter, Navy VSTOL applications, and typical Air Force Single Seat Attack efforts. Future applications such as in an Advanced Scout Helicopter or Marine Helicopter Night Vision System would pose similar display requirements. Typical field-of-view requirements for the HMD are 30 degrees vertical by 40 degrees horizontal. The exit pupil is usually 12-15 mm or greater. Since these systems must be planned for day/night mission scenarios, typical luminance levels of 1-10 ft lamberts for night and 200-400 ft lamberts for day operation are dictated. Capability for a minimum of eight 2 grey levels is required for these video displays, with a desire for 10-16 level capability. Any discussion of luminance and contrast requirements for the helmet-mounted display should keep in mind that the image displayed is a virtual image and this "see-through" scene is usually viewed against a variety of ambient back-grounds. A typical weight limit for the complete helmet system including electronics is 3.5 pounds, and this will probably be lowered as mission length and aircraft "g" tolerance increase.

The Tri-Service development thrusts toward an advanced helmet-mounted display capability highlighted previously are aimed at providing that capability to a variety of airborne (both high performance and rotary wing) and groundbased mission applications, as shown in Fig. 21. As in the case of the helmet-mounted/virtual image mode

Figure 21. Helmet-Mounted/Virtual Image Display Applicability to Airborne and Groundbased Missions

of displays when an area or areas of commonality in application and similarity in requirements exist across the services, then a Tri-Service set of development activities can be an extremely cost effective way of meeting the corresponding Army/Navy/Air Force objectives. Instead of unrelated efforts with marginal emphasis proceeding in possibly a duplicative way, a joint set of thrusts can achieve a critical mass in terms of technical expertise and resources which can be focused on the leading, highest payoff approaches. Additional benefits can be gained when there is technology transfer/spin-off commonality with other display areas. An example of this would be the utilization of one of the interim, miniature high resolution solid state display sources from the HMD activities in a quad array for advanced head-up display applications. In situations such as this, the development process is even more cost effective by satisfying an even larger number of Army/Navy/Air Force display requirements.

SESSION VII - OPEN EXECUTIVE SESSION

SESSION VII

Open Panel Discussion

Wayne L. Martin, Moderator

MARTIN: We have heard a lot of excellent presentations about a wide variety of activities across all three services. We now have a unique opportunity in this session to develop recommendations and make those visible at relatively high levels within DoD. I think we all now appreciate that the analysis that must occur to realistically project sensor, display and operator performance requirements can be a rather complex process. Perhaps we need to categorize problems as to whether we as a community can address them or whether someone at some other level would be more appropriate.

In an attempt to respond to John Johnson's direction that the Display Subpanel identify the mission requirements that drive the display technology for the 1985 to 1990 time frame, we are taking the first step in the Air Force to assure we understand the impact of mission requirements for representative systems on sensor and display performance requirements.

(At this point, Mr. John Simons is introduced and asked to present a brief talk on the mission requirements identification effort that he is doing for AMRL at Wright-Patterson AFB, Ohio)

SIMONS: We found that the way they've been flying simulated night is to use two of the levers and two different sensors and do a lot of sensor switching and a lot of sensor tuning in order to achieve ridge skips of a hundred feet or more. The imagery is quite breath-taking. We've been talking to the pilots on their techniques. I think that it is

interesting that the system was built on a very general requirement for high, medium, and low altitudes. A very generalized scenario. But now that it's in their command and they've been told that we're getting down in the weeds with this system, they're using it in a completely different way. They use the ballpark scenario, of Dr. Frick type, to generate the system and now that they have the system they are fine tuning their tactics within that system. And that's the same thing we'd like to do in this upcoming task. To pick about four aircraft and about five system configurations for each; go back to the using command and find out how they really plan to use that thing and what we're really doing is fine tuning the scenarios. For example, in the scenario usage, we found that the pilot's major concern was "pushover." When have I cleared the ridge? One of his major problems is looking at near horizons when there is a far horizon in the field-of-view. So he sits there and he retunes to "pop up" at the near horizon. When he clears that near horizon, then he wants to see the far horizon and not the near one. This is the kind of tactic they've developed. While he's doing this, he's asked the NAV on the IR to tune the IR to "hot" and look for obstacles in clouds against the full sky. So, here's two operators using two sensors in a way that you'll never find in any shape or form in the original requirement. It's that kind of thing that we'd like to do for this group.

We've picked the F-16, the A-10. I've just finished flying the A-10 in the simulator at Orlando and there's a lot of sensor tactics experience and interpreting information on that one also. It flies about the same airspeed as the B-52, just a little lower on the sensor. I would like to

comment on the basis of my AC-130 experience and my B-52 experience, on sensor design. The Air Force's most accurate killer and acquirer was the AC-130, and the management and development of that system was somewhat like TADS but a little more flexible. We went through four vehicles, changed weapons, changed sensors for all four. And as that system progressed for about a two-year period, we never really fixed design for any vehicle nor did we fix missions. They were constantly adding on to it and changing; which means that I prefer a general kind of mission analysis. A statement of the ballpark and then not get too specific and then come up with a system that is flexible, knowing full well that a system is never really used in the way it was originally designed. Slant ranges will always change as a function of weapons and tactics and changes in general mean you're working with another airplane. But you do need the ballpark scenario to scope it. And the last point I would like to make is just for flexibility. Yesterday there was a good discussion on automatic tuning. When you look at the B-52 operator and the way he tunes during a mission segment in flight, and they have already written it into their Ops program, he retunes for the type of terrain, for the type of weather, the sun illumination angle, but mostly he tunes for his strategy. What portion of the display is he most interested in at that point in time. So my feeling here would be to try to have these automated but if you can, have a manual insert, because these systems are always used so differently. I'm sure PAVE TACK would be flying quite a bit differently than it's intended to be flown, I have yet to see a system that didn't.

BURNETTE: John, I think most of us are thinking of some form of manual

trim control, once we know what we're dealing with in terms of making the thing most legible. On a CRT, we control brightness and contrast because those are two available control points. But those are not necessarily the thing that's controlling background brightness and emitted luminance and that's not necessarily the thing that you'd best like to control in any given circumstance.

SIMONS: One of the most dramatic effects in the AC-130 program was moving from point to area ordnance, where you're trying to strike a point with point ordnance. This is a whole different way of using the sensors to strike an area target with area ordnance or spread ordnance. Usually when we got to a point and beyond, we're looking for huge landmarks and then kind of bisecting the landmarks into areas on the display. But it was the same system. Here again, flexibility was, I think, quite germane.

BRINDLE: (First part non-transcribable)...pilotage, target acquisition, navigation, and I think the point you're trying to make is that a system is built and designed to do a specific one of those, once it gets on board that aircraft, that pilot will have to use it for many of the others.

(Non-transcribable comment.)

SIMONS: TADS will be flown a little differently and perhaps, used for different missions, from what it was designed.

BURNETTE: But see, what he's really saying is he wants to change the legibility of the display and what we usually have control over is the contrast and things like that. Contrast is not the same thing as legibility. The point I'm trying to make is that a guy flying an airplane, goes to some portion of a roll or a bank and a pitch maneuver which causes

shadows to go across the cockpit and all the rest. I would like to think that that display is going to continue to look to him the same as when he set it. Then, if he wants to change the effective legibility of the information in that picture, yes, he should have a control to do that. But, then again it should maintain so until he's ready for it to be different again. The point, now is, the guy sets the thing up.

SIMONS: (First part non-transcribable)...FLIR, large field-of-regard, down at the Martin-Marietta facility we just finished twenty-six TAC pilots for Single Seat Attack. It was a real bear. It took three days to really train these pilots to use both these FLIRs, manage the switchology and get down to two hundred feet. What we did was to take 10-second shots of their total switchology, flight control time history. And in that 6 minutes, they were in that dash, in strike, and in re-attack, very highly task loaded. We found that reducing workload was a misnomer, what they would do was change workloads. If you look at a 10-second chop of the total flight control and switching history, the fine tuning of the flight control was prevalent. When the task is less loaded, they changed their workload. They do a finer tuning, a higher rate of aileron deflection history, so they filled up their 10-second gap when they were not switching and steering sensors. They were flying at a higher tune, so it's sort of a plateau.

OHLENBERGER: (First part non-transcribable)...indicated the close coordination, if you will, with the using command, the design guy and the using command. Now, I've said for an awful long time that you could have the best designed piece of equipment in the world, best engineered piece

of equipment in the world, but it can easily get to the field and be worthless. And the idea of the guy that's actually doing the design work, the guy that's doing the engineering is really, he should get out there with the user guy. Army aviation as an example. He ought to be out there flying nap-of-the-earth so he knows what it's like, what kind of environment that guy is working in. (Non-transcribable discussion.) to get the root of the problem, most of the time we end up with the greatest engineered piece of equipment in the operational environment and it doesn't work, and doesn't give the user, the guy that's got to absolutely use it out there on a daily basis, doesn't give him what he needs. And it's amazing, I can come in here and talk about NOE, our sister services can talk all day long about the individual mission's aircraft, but if a guy is not there, he hasn't seen it, he's not there in the environment, doesn't have the appreciation on the ground and in the air, you know, it's the old thing like we were talking about yesterday. Put yourself in that tank seat and think about what's coming at you. Okay. You want to be sure that what's coming at you is not friendly, a friendly weapon will kill you just as well as an enemy weapon if directed from the wrong place.

DVORAK: I've got a comment. I just can't let this go by. I'd like to speak firsthand about your comment about the engineers ought to get out there and see firsthand what's happening. This was my philosophy all along. I was a project engineer working in major avionic development systems and I thought that the engineers ought to be out there to see what's happening. I requested permission to fly on the aircraft. I had so much resistance from the "green suiters" that it was almost impossible

to get in the cockpit.

OHLENBERGER: When was that:

DVORAK: This was starting back in 1965.

OHLENBERGER: That's old, that's history.

DVORAK: I finally got authorization to fly and I did fly. I got authorization to fly as a pilot in Vietnam but there was so much opposition that it just was a struggel trying to get in the cockpit.

OHLENBERGER: But the thing is, those are the struggles we've got to overcome. You know (rest non-transcribable.)

DVORAK: I'm the only engineer at Ft. Monmouth that was ever authorized to fly on the aircraft and I'll guarantee you today that if I tried to do it over again, it would be the same story.

OHLENBERGER: But are you talking about flying, you mean being checked out and to go out and fly? Is that what you're talking about?

GURMAN: He did the whole thing.

OHLENBERGER: I'm talking about getting out there with a qualified pilot in the cockpit, taking the guy through the procedures, that's easily done. You don't have to, if you will, go through the pilot qualification for the Army, the Air Force or the Navy as an engineer to get the appreciation for what needs to be done, that's not necessary. But the fact is, of being out there in the environment, whether you're working on an aviation system or a ground system, being out there. If it's a tank system, get out there and play around with the tank.

ANONYMOUS: I think that just a demonstration flight is not enough, you've got to get out there.

BURNETTE: You have to perform a task yourself, that's it.

(Non-transcribable interchange.)

GURMAN: I was involved with some studies. I was designing equipment and I made some of the approaches, because I had faith in what I thought I was designing. Now that I know better, I wouldn't do it. I think that's really the case. I think design engineers are reluctant to go flying because they know what the probabilities of the equipment working are. They don't have confidence in the pilot, they don't have confidence in their own scores.

OHLENBERGER: You see, that goes back to the old business of having your crew chief fly on your own aircraft. From the time I walk out to the aircraft, if the crew chief won't fly it, I'm not going to fly it either. If the engineer gives me a piece of equipment that he's not confident in, then I don't want it in my aircraft.

SCHLAM: (First part non-transcribable) I guess you get the same thing, but rather than going into a national aircraft that maybe doesn't have the flexibility to take the engineering changes, we've been talking about test vehicles. And I think perhaps, this is a good, at least to me, approach to get more test vehicles that are versatile enough.

BRINDLE: That's right. There's more engineering devices in 6.3 level than can be tested out. You know, maybe we don't have all the answers pegged down pat.

GURMAN: I think that the rule that the engineers fly their own equipment is not a bad idea.

SCHLAM: I think perhaps, even, that ground simulation tables might be better.

OHLENBERGER: You can do a lot with simulators because we're getting some real good simulators. We can get a real feel for that, and that's probably the first step. But then it's the time when you're working with such things as night vision equipment that you can't get the full feel of what's going on in the problem unless your butt's strapped down in the aircraft seat.

(END OF TAPE)

(After a delay)... exploratory development, advanced development areas, by which, as you go down through the development slices, you come up with an aviation system that is being designed, given say the AAH as an example, that PM does not have the proper "shopping list" of equipment available for him to stick in that airplane because that work initially hasn't been done or hasn't been progressively going down the road of development because we've had a lack of the guys in the munitions area developing concepts. Not today's concepts, but concepts for '86, '90, '95 time frames that drive the development efforts that gets the money to do those things with, justify to Congress and all that, because the prof heads have had their heads stuck in the sand. We've been training, but we haven't been developing worth a darn. Not that there hasn't been a lot of good work going on, but I'm saying, you can't say now I want an aircraft that's going to meet an IOC of '82 and start trying to accelerate and put equipment in it that is not going to be ready before '82. But in order for him to do his job, he needs some added capabilities that haven't been defined far enough ahead.

FRICK: You know, I don't see any difference in the way you're seeing display technology and any other technology. You know there's always a

problem with looking at things in a systems context. The mission area analysis is, at least for the Air Force, being done by both the using command and Air Force Systems Command. Furthermore, in the Air Force a year ago we started what is called the Avionics Planning Conference. I know the display people representatives on that, we have two of them. Bob Hilgendorf is the first and the second is Jim Feliccia from the Flight Dynamics Lab. So I think a lot of this is being done. On the one hand I think we either have a systems approach and maybe on the other hand we should not have too much of a systems approach so as not to stifle the innovative process. You know electronic warfare had a big problem for many years, and I guess they still do. There's such a myriad of ECM programs and not any kind of master plan, so ASD is now coming up with an EW master plan.

FULTON: (First part non-transcribable)...you the user, the systems people, all the technologists are here for the first time. By the note taking, the question asking, I didn't know this, I didn't know that, the various specific comments, you've accomplished a great deal. You've come across a lot of problems which you haven't been able to solve right now, so what you put together is a living document.

BRINDLE: So what you're saying is, what we need to do from the transcription of what's taken place in these kinds of discussions is to highlight some of those problem areas along with some recommendations for their solution.

OHLENBERGER: And out of that, and I beleive that I have been provided with some of this stuff, there are certain areas in the technology, or certain

things you guys see that need to be done. And I'm talking about looking at something that can be productive. I need to know, if you will, what some of these areas are so that I can begin to prod the things like the STOG and ask for some capabilities. You guys can tell me that you see gaps in the technology, things that are not being done in industry that are going to have to be done for the peculiar missions that we have and the goal of them. I need to know about some of these because then I can, from the Army's standpoint, begin to prod and try to get some of these areas emphasized. I can talk to people as long as I'm in that office and that's fine. But I've got to get it in some kind of document because when I leave or go to something else or retire or whatever, it's got to be written down somewhere or that thing dies.

GURMAN: Okay, I'm going to take you up on that. But I'm going to go even further than that, I'm going to help you, offer to help you, to help write the rest of the requirements.

OHLENBERGER: The only thing is, I don't want you to write me a draft requirements document.

GURMAN: I'm not going to write you a draft requirements document. I'm going to try to sell it to you.

OHLENBERGER: That's what happens. That's what happens too often. The first time I see a draft requirements document from a material developer and, I'll, everything turns red around me and my first tendency is to toss it. I need to know where you guys are seeing the gaps, because we've been remiss on your side of the house. I can't do everybody's job. I can't for example, do all the concepts work. I've been doing a lot of

it, but I can't do all that and keep up with what's going on in the system, writing requirements documents and then keep up with the Product Improvement Programs; it's just physically impossible. But I can get some of these things into certain kinds of requirements documents.

BURNETTE: Cliff, quick question. I may be a little confused about this. Please straighten me out. Isn't your shop primarily to develop requirements?

OHLENBERGER: My shop builds the requirements documents but that's based on what another part of the shop does. And I'm talking about the concepts and doctrine boys and the threat shop. As they see changes in threats, they supposedly project out to the 1990's, and they build concepts. I take these concepts and develop the requirements document.

(Non-transcribable segment.)

OHLENBERGER: We're talking about a display workshop and all I've heard about is one facet of displays. There are a lot of other things that have to be done to free the pilots in the cockpit and so far we've talked about only one real part of it. I mentioned getting rid of a lot of instruments in the cockpit that the guy doesn't need to look at continuously. Every day systems are all go 99.9 percent of the time.

BURNETTE: The MENS of the Air Force are, in the new aircraft, putting in message devices, static displays, whatever you call them, and incorporate all that data, prioritize (rest non-transcribable).

TASK: The limitations of this meeting is supposed to be primarily for imaging dipslays. That is the limitation of our Charter, I'm afraid.

MARTIN: Imaging displays for airborne applications (non-transcribable segment). You've heard a lot about the interaction, and the lack thereof,

between the operational community and the engineering design community. You've heard from John Simons regarding an alternate approach to the problem that has been taken by the Air Force to assure that we have the tactics worked in there, and that you can cover the two.

SCHLAM: Wayne, I think what we uncovered in the last three days isn't indigenous to the Army, Navy or Air Force and I think that we should write a story that is service independent.

MARTIN: The problem is, we're doing that yes, in terms of defining problems that we in the display community can address.

SCHLAM: You can write recommendations that are service independent.

MARTIN: That's correct, but that's a different activity than what I had in mind.

GURMAN: You see if we're talking about display technology advancement, that technology advancement really isn't tri-service. If we look at it from only the Army's point of view we might say this is what we see as best for us but doesn't necessarily have applications in the other services. Just as when the Air Force is developing something, they're going to develop something, we're going to look back and see what is feasible from here. The helmet device, for example, is being funded by three services, obviously not a single service point of view.

MARTIN: But my point is that in predicting the factors, "Can we predict the weapon systems in which the helmet mounted displays may be used to render them more or less suitable in terms of satisfying mission requirements for the Army vs the Air Force?" That's all I'm saying and that's why you have to consider the weapon system involved, the tactics,

the theatre of operation, the whole nine yards. And that's why the plan for the services as to how we get from here to there in terms of defining what our system requirements are will probably be different though they'll have some commonality.

GURMAN: I'm sorry I don't see it that way. From my years of system's experience, it tells me that despite the ways that you can differentiate between several Air Force requirements, and several Navy requirements, and several Army requirements, they're not that greatly different. When it comes down to the materials that you are going to use in your system, they're not much different. We've found in the display area already, that whether we call it the Air Force's development, the Army's development, or the Navy's development, we're going to the same place.

MARTIN: But why then don't we see your HMDs being applied in the Air Force to the extent they are in the Navy.

GURMAN: I don't think that's the point.

SCHLAM: Let's write down what we've learned during the past three days and see what it looks like. I don't think we can do anything more.

BRINDLE: I think Elliott is right. I think as a minimum we need to come out of the transcription of all this with some problem areas...

MARTIN: Absolutely.

BRINDLE: ...that we see, that we in the display community see, to send to somebody. Who that somebody is, I'm not sure.

FULTON: Wayne, if ODDR&E were to ask you "What are the display problem areas, how you plan to address them, etc.?" would you be able to answer them based on what has transpired here?

MARTIN: No.

REDFORD: Well your first answer to ODDR&E is going to be no. The next thing is you're going to say is why. And then perhaps make some recommendations about how we can get this together and then continue.

MARTIN: But you see that sort of recommendation across the services is what I'd like to see in the individual plans from the individual services.

MYSING: And then do you intend to meld these together? Now you're going to then now identify the commonality and bring it together?

MARTIN: Right, absolutely.

VERONA: Let's point out the commonalities.

MYSING: I think he's saying that if he saw the individual plans, then you can identify the commonalities.

(Non-transcribable discussion.)

VERONA: What about the four tasks we had up there yesterday - pilotage, navigation, target acquisition and weapon delivery.

GURMAN: Do you have a single plan within the Air Force?

(Non-transcribable segment.)

BURNETTE: Well wait a minute, you know, let's not use technology in this thing and try to wag the dog.

GURMAN: We're trying to avoid that, that's the exact point. That's what I'm saying, that's the point.

BURNETTE: All we can do is write down what we've learned.

GURMAN: All right, we've identified the fact that displays do not right now satisfy the MENS and that work has to be done and some of the reasons why they have to be done.

(Non-transcribable segment.)

(Dr. Schlam goes to blackboard and writes down recommendations.)

List of recommendations:

1. System display development efforts should be evolutionary in nature, an iterative process, with options for technology insertion.

2. There is insufficient user/developer/designer interaction.

3. There is a gap between display technology base (6.2) and system development (6.4), which must be filled by 6.3A work.

4. We don't understand the man-machine interface sufficiently well to properly spec display needs (e.g., resolution, size, interaction, cuing, tuning).

5. There is a lack of concepts for future systems based on anticipated military needs to drive the technology base.

6. There is a need for "real world" analysis, study, and flight test simulation of system/device configurations based on user needs.

7. There is a void in the application of state-of-the-art technology to systems development because of the lack of 6.3A funding.

8. We don't use (or have not developed) systems integration concepts/tools well enough to properly trade-off between subsystem capabilities.

9. There is insufficient attention spent on displays except when they appear not to do their job.

10. The display requirements necessary to perform specific tasks (e.g., navigation, pilotage, target acquisition, weapon delivery) have not been sufficiently defined; and that definition is not a simple process (see #6).

11. It is apparent that display technology and display systems development across the services is being pursued in a non-duplicative way, and that in fact there are voids where added emphasis is required.

12. Common and valid measures of operator workload with regard to displays and other aircraft subsystems are needed.

13. We need standardized display/sensor measurement techniques.